Biomass Estimates and Biological Reference Points for Flatfish Species Resident to the Coast of British Columbia, Canada

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Abstract

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Data from the Hecate Strait Assemblage bottom trawl survey conducted from 1984 to 2003 were used to estimate the biomass of flatfish species in Hecate Strait. In addition, fishing reference points were estimated from spawning stock biomass per recruit analysis for the four main commercial species. The biomass of Pacific Sanddab, rex Sole, flathead Sole, Rock Sole, Slender Sole, Dover Sole, English Sole, Curlfin Sole and sand Sole increased over time while the biomass of Arrowtooth Flounder, Starry Flounder and Petrale Sole was stable and Butter Sole biomass decreased slightly over time. Arrowtooth Flounder, English Sole, rex Sole, Dover Sole and Rock Sole accounted for more than 75% of the mean annual biomass and 76% of the biomass for all years combined. Biomass estimates for commercial species from this study were similar to estimates from catch-age-analysis used in stock assessment. Calculated exploitation rates for 2003 were low for all species, probably due to low fishing effort in the Strait in recent years. The most conservative reference point for all four species was that corresponding to the 25th percentile of the SSB/R, F_{high}. The fishing rate F_{high} allowed rebuilding of depleted populations within a decade. The reference points F_{rep}, F_{msy}, $SPR_{50\%}$, $SPR_{40\%}$, F_{low}, and $SPR_{35\%}$ produced yields sustainable in the long term with remarkable consistency for all four species. The threshold replacement level occurred at F = 0.11 for Dover Sole, F = 0.20 for English Sole, F = 0.18 Rock Sole and F = 0.08 Petrale Sole. The reference points $SPR_{40\%}$ and $SPR_{50\%}$ prevented recruitment overfishing in the case of Dover Sole while $SPR_{50\%}$, F_{low}, and $SPR_{40\%}$ prevented this for English Sole, $SPR_{40\%}$ and F_{low} prevented it for Rock Sole and $SPR_{50\%}$ and $SPR_{40\%}$ prevented this for Petrale Sole. Annual surplus production peaked at 1100 t for Dover Sole, 900 t for English Sole, 850 t for Rock Sole and 550 t for Petrale Sole.

Résumé

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Les données du relevé au chalut de fond des assemblages dans le détroit d'Hécate effectué de 1984 à 2003 ont servi à estimer la biomasse d'espèces de poissons plats dans le détroit d'Hécate. De plus, les points de référence en matière de pêche ont été estimés à partir de l'analyse de la biomasse par recrue des stocks reproducteurs pour les quatre principales espèces commerciales. La biomasse de la limande sordide, de la plie royale, de la plie à tête plate, de la fausse limande, de la plie mince, de la limande-Sole, du carlottin anglais, de la plie à nageoires frisées et de la plie à points noirs a augmenté au fil du temps tandis que celle de la plie à grande bouche, du flet étoilé et de la plie de Californie est demeurée stable et celle de la plie à écailles régulières a légèrement diminué. La plie à grande bouche, le carlottin anglais, la plie royale, la limande-Sole et la fausse limande représentent plus de 75 % de la biomasse moyenne annuelle et 76 % de la biomasse toutes années confondues. Les estimations de la biomasse pour les espèces commerciales faites dans cette étude étaient similaires aux estimations des analyses de prises selon l'âge utilisées dans les évaluations des stocks. Les taux d'exploitation calculés pour 2003 étaient bas pour toutes les espèces, et c'est probablement en raison des faibles efforts de pêche dans le détroit au cours des dernières années. Le point de référence le plus prudent pour les quatre espèces était la correspondance avec le 25^{e} centile de la biomasse par recrue des stocks reproducteurs, f_{high} (taux de mortalité élevé). Le taux de pêche F_{high} a permis le rétablissement de populations épuisées en moins de dix ans. Les points de référence F_{rep} (remplacement), F_{msy} (production maximale soutenable), $SPR_{50\ \%\ (géniteurs\ par\ recrue)}$, $SPR_{40\ \%}$, F_{low} (taux de mortalité faible), et $SPR_{35\ \%}$ ont fourni des rendements soutenables à long terme avec une cohérence remarquable pour les quatre espèces. Le seuil de niveau de remplacement se situe à F = 0,11 pour la limande-Sole, à F = 0,20 pour le carlottin anglais, à F = 0,18 pour la fausse limande et à F =0,08 pour la plie de Californie. Les points de référence $SPR_{40\ \%}$ et $SPR_{50\ \%}$ ont empêché la surpêche du potentiel reproducteur dans le cas de la limande-Sole tandis que $SPR_{50\ \%}$, F_{low} et $SPR_{40\ \%}$ l'ont fait pour le carlottin anglais, $SPR_{40\ \%}$ et F_{low} l'ont fait pour la fausse limande et $SPR_{50\ \%}$ et $SPR_{40\ \%}$ l'ont fait pour la plie de Californie. La production excédentaire annuelle a atteint son apogée à 1 100 t pour la limande-Sole, 900 t pour le carlottin anglais, 850 t pour la fausse limande et 550 t pour la plie de Californie.

INTRODUCTION

There are twenty-two known pleuronectids resident off the coast of British Columbia, including twenty right-eyed and two left-eyed species. They encompass a wide range of life history characteristics and have adapted to a diverse environment. The most abundant stocks off British Columbia are those in Hecate Strait, a ~25,000 km^2 area separating the Queen Charlotte Islands and the B.C. mainland (Figure 1). The flatfish assemblages in Hecate Strait are dominant over a depth range of 10 to 80 fa with persistent boundaries found in the 25-30 fa range and 50-60 fa range (Fargo and Tyler 1991). There are both regular and seasonal components in these assemblages.

The commercial trawl and longline fisheries in Hecate Strait date to the early 20^{th} century while the Haida First Nation fishery extends back thousands of years (Fargo 2005). Pacific halibut Hippoglossus stenolepis is the dominant flatfish species in the longline. It is assessed and managed by the International Pacific Halibut Commission (IPHC) and will not be included in this report. The flatfish species most important to the commercial trawl fishery of this region are: English Sole (*Parophrys vetulus*), Dover Sole (*Microstomus pacificus*), Petrale Sole (*Eopsetta jordani*), Rex Sole (*Glyptocephalus zachirus*), two species of Rock Sole (*Lepidopsetta bilineata* and *Lepidopsetta polyxystra*) and Arrowtooth Flounder (*Atheresthes stomias*). Minor components are: Flathead Sole (*Hippoglossoides elassodon*), Slender Sole (*Lyopsetta exilis*), Butter Sole (*Isopsetta iSolepis*), Sand Sole (*Psettichthys melanostictus*, Curlfin Sole (*Pleuronichthys decurrens*), and Starry Flounder (*Platichthys stellatus*).

Formal assessment of stock status for the region did not begin until the late 1970s however research and supporting data collection have been conducted since the late 1940s. Yield for all of these species is highly dependent on recruitment which fluctuates over time due to changing environmental conditions. Most recently stock assessments have employed Bayesian catch-at-age methods (Fargo et al. 2001). A broad spectrum of input is necessary to support this type of assessment. This includes but is not limited to, life history characteristics, research survey abundance estimates and information on the relationship of parent stock and recruitment. The reference point of $F_{0.1}$ has been used as a target for management of these species (Fargo et al. 2001).

Estimates of absolute abundance are developed here for 13 flatfish species in Hecate Strait using research survey data collected between 1984 and 2003. In addition, traditional spawning stock biomass per recruit analysis is used to estimate twelve reference points that could be used for management of the four main commercial species. Although this information may be useful for stock assessment in the future this document is not intended as a stock assessment document and contains no information on stock status or advice to managers.

METHODS

BIOMASS ESTIMATION

The details on the bottom trawl survey design and operation are contained in (Fargo et al. 1984, Westrheim et al. 1984, Fargo et al. 1988, Antonsen et al. 1990, Wilson, et al. 1991, Hand et al. 1994, Workman et al. 1996, Workman et al. 1997, Choromanski et al. 2002a, Choromanski et al. 2002b, Choromanski et al. 2004, Choromanski et al. 2005). The survey catch consisted of juveniles and adults of all species. The overall mean catch-per-unit effort, CPUE, was used to estimate abundance for each species for each survey. The overall mean was used because of the systematic design of the survey. Survey tows were distributed homogeneously over a depth range of 10 – 79 fathoms (fa, 18-145 m). CPUE data for usable hauls on the Hecate Strait surveys were $\log_e$ transformed to meet the assumption of normality for statistical analysis. The bootstrapped, transformed data were used to estimate the mean and 90 percent confidence interval. The mean and confidence interval of the transformed data were back transformed to estimate biomass by expansion. The same procedure was applied to CPUE data for the 10th and 90th percentiles of each species' depth distribution to produce a second set of indices for comparison. The estimate of the amount of area in Hecate Strait (10 fa-79 fa), used in the biomass calculation, was produced using ArcView GIS software (Sinclair et al. 2007).

The following equations were used in the estimation of biomass:

- the biomass using swept area of the doors - $B_d = \overline{CPUE}(A) / A_d(q_1)$
- the biomass using swept area of the net - $B_n = \overline{CPUE}(A) / A_n(q_2)$

where: $\overline{CPUE}$ is the mean CPUE for the survey, A is the total area, A_d is the area swept by the doors in one hour, A_n is the area swept by the net in one hour, q_1 is the catching coefficient for the doors and q_2 is the catching coefficient for the net.

The following measured quantities were used in the estimation procedure:

Total area	2360 nm^2
Distance between doors	60.0 ft
Area swept by the doors in 1 hour	0.0247 nm^2
Catching coefficient	0.6
Average area swept by doors per tow	0.0922 nm^2
Net spread	34.5 ft
Area swept by the net in 1 hour	0.0142 nm^2

Catching coefficient	1.0
Average area swept by net per tow	0.0530 nm^2
Vessel speed	2 .5 nm/h

ESTIMATION OF REFERENCE POINTS

Population simulations

Results from a population simulation model, detailed below, were used to investigate the effects of fishing on the populations of west coast Vancouver Island Dover Sole and Petrale Sole and Hecate Strait English Sole and Rock Sole. One hundred simulations were done for each species. The data used for the simulations were for females only. Females comprise the majority of the harvest (by weight) of these species and most of the catch in numbers. Two stock recruitment relationships were used in the simulations, 1) Beverton and Holt (1957), $R=P/(a+(bP))+\varepsilon$, 2) Ricker (1954), $R=a(Pe^{-bP})+\varepsilon$. These were fit to parent, P, and recruitment, R, indices developed from catch-at-age analysis for Hecate Strait English Sole, Rock Sole and west coast Vancouver Island Petrale Sole. There was no catch-at-age analysis available for west coast Vancouver Island Dover Sole and two other data sources were used to develop population indices: 1) population estimates from surplus production modelling (Prager 1992) and 2) population indices from the latest Dover Sole catch-at-age analysis for the Oregon coast (Sampson, unpublished data) scaled to west coast Vancouver Island Dover Sole landings. West coast Vancouver Island Dover Sole spawn in deepwater during winter and oceanographic events on the open coast affect survival of the larvae which can remain in the water column for up to two years (Sampson and Wood 2000). Thus there may be extensive mingling of larvae along the shelf break.

Simulations were done for each species with and without variation around the stock-recruitment relationship and with recruitment determined as a random variable with a mean and standard deviation equal to the observed recruitment time series. The fit of each stock-recruitment model was examined using least squares methods. The mean square error, MSE, was used to compare the model fits. This was calculated by dividing the sum of squares for predicted, e, and observed, o, recruitment from each model by the number of years, n.

Population simulation model

The change in population numbers for a series of years is:

$$N_{ij} = N_{ij}\, e^{-(F_{ij}+M_i)t}$$

Where N is numbers, F and M are the instantaneous rates of fishing and natural mortality, respectively and i and j index age class and year.

Carrying ages over time,

$$N_{i+1,\,j+1} = N_{ij}=N_{ij}\, e^{-(Fij\,+\,Mi\,)}$$

Recruitment into the population at the start of the year is a function of the spawning stock at time s on the pth year prior to that under consideration and the proportion of mature fish, s, at age.

$$N_{ij} = f\{N_{1,j-p}(s),\ldots,N_{m,j-p}\,(s),\ n_1,\ldots..,n_m\}$$

Growth of individuals at age expressed using the Bertalanffy growth curve is,

$$W_i = W_\infty\,(1 - e^{-kt})^3$$

Weight yield was calculated separately for each age group j in each year i.

$$Y_{ij} = \sum_{i=1}^{m} F_{ij}N_{ij}W_{ij}$$

Long-term yield, Y_N, from a simulation run was,

$$Y_N = \sum_{i=1}^{m}\sum_{j=1}^{n} Y_{ij}$$

where i indexes year from 1 to 100 (m) and j indexes age group from 1 to 10 (n) for English Sole and Rock Sole, 1 to 20 for Petrale Sole and 1 to 30 for Dover Sole.

Yield per recruit analysis

Results from the population simulations was used to determine the yield per recruit, Y/R, for each species to determine the reference point $F_{0.1}$, the point on the yield per recruit curve that is equal to 10% of the slope of the curve at the origin (Anthony 1982) and F_{max}, the point where the slope of the yield per recruit curve is equal to zero and the fishing rate produces the maximum yield per recruit.

Spawning stock biomass per recruit analysis

Results from the population simulations were also used for spawning stock biomass per recruit analysis, SSB/R, using the procedure of Mace and Sissenwine (1993). The recruitment model cases investigated are listed in Table 1. Results of the SSB/R analysis were used to estimate the fishing rate associated with a reduction of spawning biomass to 50%, $SPR_{50\%}$, 40%, $SPR_{40\%}$, 35%, $SPR_{35\%}$, 30%, $SPR_{30\%}$ and 20%, $SPR_{20\%}$, of the unfished level and the fishing rate associated with maximum yield, F_{msy}. Similarly, fishing rates were estimated that corresponded to the median, F_{rep}, the 25th percentile, F_{low}, and the 75th percentile, F_{high} of the survival ratios, R/SSB(Mace and Sissenwine 1993). Steepness was also estimated in two ways: 1) as the ratio of recruitment at a spawning stock size 0.2 of B_0 divided by recruitment at B_0 using results from the simulation model. 2) as the ratio of recruitment at a spawning stock size 0.2 of B_0 divided by recruitment at B_0 using the stock recruitment relationship without error.

Annual surplus production

Annual surplus production, *SP*, was calculated as,

$$SP_t = B_{t+1} - B_t + C_t$$

where B_t is the biomass in year t and B_{t+1} is the biomass in year $t+1$ and C_t is the catch in year t.

RESULTS

BIOMASS ESTIMATION

Depth distribution

Boxplots of the depth distribution of each species across all surveys are presented in Figure 2. Median depth was within the range of 18-60 fa for all species. The overall depth range encompassed 10 to 120 fa (fathoms). However depths deeper than 79 fa were only used for an ecological study (Fargo, In press). Starry Flounder, Curlfin Sole and Sand Sole occupied the shallowest depths (18-30 fa) while Flathead Sole and Slender Sole occupied the deepest depths (50-70 fa). The species having the narrowest range of depth distribution was Starry Flounder while Arrowtooth Flounder, Rex Sole, Flathead Sole, Slender Sole and Dover Sole had the greatest range. Median depth ranged from 16 fa for Starry Flounder to 58 fa for Slender Sole. The 90% ci for each species covered a range of about 20 fa. There was virtually no change in the average depth occupied over time for any species (Figure 3 and 4). Although most species showed a slight decreasing trend over time (not significant).

CPUE

CPUE was used to estimate biomass for each species (Tables 2 and 3). CPUE distributions were normalised with a natural log transformation. The backtransformed mean of the bootstrapped ln(CPUE) was used for biomass estimation. The distribution of the bootstrapped replicates of ln(CPUE) is presented for each species by year in Figure 5. The distribution of replicates met the test for normality for most cases. Exceptions were the distributions for Butter Sole in 1987, Slender Sole in 1984, Starry Flounder in 1984, 1987 and 2003 and Curlfin Sole in 1987 where a paucity of data was available.

The backtransformed mean of the ln(CPUE), hereafter referred to, as $CPUE_2$, was lower than the mean of the untransformed CPUE for all species (Figure 6). There was little difference in trend between $CPUE_2$ for all depths and $CPUE_2$ using data corresponding to the 10^{th} and 90^{th} percentiles of the depth distribution for each species (Figure 7). The highest $CPUE_2$ obtained was for Arrowtooth Flounder while the lowest obtained were those for Curlfin Sole and Starry Flounder.

The cumulative frequency of the coefficient of variation, CV, for $CPUE_2$ replicates is presented in Figures 8-10. The CV was 0.3 or less for 79.3% of the cases. This level of CV was deemed acceptable for groundfish stock assessment work (Sinclair et al. 2003). The CV was 0.4 or less for 95% of the cases.

Biomass

Biomass estimates and their 90% confidence interval for the area swept by the net (using data for all depths) is presented by species in Figure 11. Biomass estimates based on the data from the 10^{th} and 90^{th} percentiles of the depth range for each species are shown in Figure 12. The trends between the two types of estimates were very similar and I refer to the estimates using data for all depths in the following discussion. The biomass of Pacific Sanddab, Rex Sole, Flathead Sole, Rock Sole, Slender Sole, Dover Sole, English Sole, Curlfin Sole and Sand Sole increased over time while the biomass of Arrowtooth Flounder, Starry Flounder and Petrale Sole was stable and Butter Sole biomass decreased slightly over time. Arrowtooth Flounder made up the highest proportion of the biomass for all years except 1993 when English Sole biomass was the highest (Figures 13 and 14). Arrowtooth Flounder, English Sole, Rex Sole, Dover Sole and Rock Sole accounted for more than 75% of the mean annual biomass and 76% of the biomass for all years combined (Figures 15-16). The biomass of all species combined increased slightly from 1984-2003 but the increase was not significant (Figure 17).

A summary of the mean, minimum and maximum biomass for each species is contained in Table 4. Independent estimates of biomass for comparison with

those calculated here were available for Arrowtooth Flounder, Rock Sole, English Sole and Dover Sole. A biomass survey for Arrowtooth Flounder was conducted in 1980 (Fargo et al 1980) and the estimate for the area swept by the net was 32600 t. This compares to a range of annual biomass estimates for Arrowtooth Flounder here of 8527 t to 32969 t (all depths). The range of exploitable biomass for English Sole females from catch-age analysis in the last stock assessment was 1000 t to 5000 t of females (Fargo 2001). The range of annual estimates of total biomass here was 5620 t to 13251 t. The exploitable biomass of Rock Sole females from catch-age analysis in the last stock assessment ranged from 1000 t to 6000 t (Fargo et al. 2001). The range of estimates of total biomass for Rock Sole from this study was 2632 t to 8756 t. Similarly, estimates of the exploitable biomass of Dover Sole from surplus production analysis ranged from 6500 t to 14400 t. Estimates of the annual biomass of Dover Sole here ranged from 3347 t to 13352 t.

Exploitation rates

A summary of exploitation rates calculated using the above biomass estimates and trawl catch in Heacte Strait for 2003 are contained in Table 5. The estimates for the main commercial species were: 0.038 for Petrale Sole, 0.043 for English Sole, 0.067 for Dover Sole and 0.121 for Rock Sole. Exploitation rate estimates for the non-commercial species were very low, ranging from 0.001 for Slender Sole to 0.050 for Arrowtooth Flounder. The estimates for the commercial species; Dover Sole, English Sole and Rock Sole and Petrale Sole are lower than estimates for these species from the last stock assessment (Fargo 1995, Fargo and Kronlund 1997, Fargo 1998, Fargo 1999, Fargo 2000 and Fargo et al. 2001). Hecate Strait trawl fishing effort has dropped considerably since the late 1990s due to a conservation closure for Pacific cod. The low exploitation rates for Dover Sole, English Sole and Rock Sole appear to reflect the lower fishing effort in the Strait. The low exploitation for Petrale Sole reflects the fact that Hecate Strait is not prime habitat for that species and the majority of the annual catch comes from the west coast of Vancouver Island.

Reference points

Yield per recruit analysis

Population simulations were done for west coast Vancouver Island Dover Sole and Petrale Sole and Hecate Strait English Sole and Rock Sole. Results of the yield per recruit analysis, YPR, are presented by species in Figure 18. The estimate of $F_{0.1}$ for Dover Sole, English Sole, Rock Sole and Petrale Sole was, 0.20, 0.34, 0.30 and 0.17, respectively. The shape of the YPR curve was similar for the first three species and $F_{0.1}$ was well discerned from F_{max}. In the case of Petrale Sole, however, these reference points were more closely associated and YPR dropped off more quickly after F_{max} than for the other species.

Spawning stock biomass analysis

A summary of stock recruitment model cases fit is presented in Table 6. Case model fits and estimates of steepness are contained in Table 7. The fitted stock-recruitment curves are presented in Figure 19. The lowest Mean Square Error (MSE) achieved for Dover Sole was using model case 1, the Oregon coast indices and a Ricker (1954) stock-recruitment relationship. The lowest MSE for English Sole, Rock Sole and Petrale Sole was obtained using the indices from catch-age-analysis and a Beverton-Holt stock recruitment relationship. Steepness, h, was estimated at 0.785 for Dover Sole, 0.592 for English Sole, 0.556 for Rock Sole and 0.823 for Petrale Sole.

The results of the spawning stock biomass per recruit analyses, SSB/R, and reference point estimates are presented in Tables 8-12 and Figure 20. The most conservative reference point for all four species was that corresponding to the 25th percentile of the SSB/R, F_{high}. The second most conservative reference point was F_{rep} for Dover Sole, English Sole and Petrale Sole and $SPR_{50\%}$ for Rock Sole. The reference point F_{crash} occurred at a fishing rate so high that all of these populations were driven to extinction (< 10% of the initial spawner biomass). This occurred in 20 years for Dover Sole, 8 years for English Sole, 5 years for Rock Sole and 4 years for Petrale Sole. The reference point $SPR_{20\%}$ presented a high risk for all populations with a marginal gain in SSB/R. A constant rate of fishing equivalent to $SPR_{30\%}$ and $SPR_{20\%}$ was not sustainable in the long term (> 20 years) for any of the species. However, populations could rebuild from the fishing rate of $SPR_{30\%}$ with fishing reduced to F_{high} for a decade. The reference points F_{rep}, F_{msy}, $SPR_{50\%}$, $SPR_{40\%}$, F_{low}, and $SPR_{35\%}$ produced yields sustainable in the long term with remarkable consistency for all four species.

The correspondence of reference points between the two stock recruitment formulations is shown in Figure 21. For Dover Sole, reference points were fairly consistent regardless of the stock recruitment relationship while for English Sole reference points F_{high}, F_{rep} and F_{low} were higher, nearly double, for the Ricker formulation than for the BevHolt formulation while F_{crash} was lower. For Rock Sole the reference points F_{rep}, F_{msy} and F_{crash} were higher using the Ricker formulation. For Petrale Sole, F_{crash} was substantially higher, 1.78, using the BevHolt formulation compared to 0.75 using the Ricker formulation. The other reference points did not differ appreciably between the two stock recruitment formulations.

The threshold replacement level was estimated using survival ratios, R/SSB, for each species (Figures 22-25). The reference point F_{rep} is considered to be an overly conservative fishing threshold for stocks close to B_0 with a strongly-compensatory stock-recruit relationship. In contrast, a negative value for F_{rep} implies that the population is unable to replace itself even in the absence of

fishing. The threshold replacement level for Dover Sole occurred at F = 0.11 (Figure 22). The corresponding figures for English Sole, Rock Sole and Petrale Sole were 0.20, 0.18 and 0.08, respectively (Figures 23-25). Thus, if F_{rep} is an appropriate measure of the recruitment overfishing threshold, adoption of $F_{0.1}$, as management target would not necessarily prevent a recruitment overfishing scenario for these species. The reference points $SPR_{40\%}$ and $SPR_{50\%}$ would prevent recruitment overfishing in the case of Dover Sole. The reference points $SPR_{50\%}$, F_{low}, and $SPR_{40\%}$ would prevent this for English Sole, $SPR_{40\%}$ and F_{low} would prevent it for Rock Sole and $SPR_{50\%}$ and $SPR_{40\%}$ would prevent this for Petrale Sole.

Annual surplus production

Annual surplus production, ASP, curves are presented in Figure 26. For Dover Sole ASP peaked at 1100 t at a fishing rate of 0.2 while for English Sole it peaked at 900 t with a fishing rate of 0.25, for Rock Sole at 850 t with a fishing rate of 0.18 and for Petrale Sole at 550 t with a fishing rate of 0.24. The curves were skewed right for all species. In the case of Dover Sole ASP is stable over a greater range of fishing rates than for the other species. In the case of Petrale Sole both limbs of the curve are steeper than for the other species implying a more dramatic decline in ASP over a similar range of fishing rates.

DISCUSSION

The only biomass estimates in this document that I view as questionable were those where the data was insufficient. This includes the estimates for: Butter Sole in 1987, Slender Sole in 1984, Starry Flounder in 1984, 1987 and 2003 and Curlfin Sole in 1987. The estimates for major commercial species were close to the range of the independent estimates available from other analyses. In the case of English Sole, where the discrepancy between exploitable biomass and total biomass was the largest, there may be a reason. That is, most males of this species do not attain commercial size. Thus the estimate of total biomass would be substantially larger than any estimate of exploitable biomass. The estimates for the minor species are the first ever produced for this area. And they may be useful in the future for status reports required by COSEWIC.

Flatfish species as a group are fairly resilient compared to many other species groups (Mace and Sissenwine 1993, Fargo 2005). One reason for this is that they are distributed more evenly over the bottom, except during spawning, and are virtually invisible to modern hydroacoustic equipment. Thus the increase in fishing power that this equipment has provided over time for aggregating species is dampened for flatfish (it does, however, provide information on bottom type which is correlated with flatfish species distribution and abundance). Despite this, some flatfish stocks around the world have been depleted. Rebuilding under reduced fishing rate or closure has been largely successful in the north Atlantic, north Pacific and the North sea (Fargo 2005). Probably the greatest threat to long term survival of these populations, other than large scale environmental change, is recruitment overfishing. The highest possibility of avoiding this, as results from this study suggest, is by selecting the target reference points of F_{rep}, $SPR_{50\%}$ and $SPR_{40\%}$. A target reference point of F_{high} appears to allow rebuilding of depleted stocks without complete elimination of the fishery (provided the stock >10% of B_0).

Estimation of absolute abundance will always be troublesome. The same gear was used for all surveys but vessels other than the research vessel W.E. Ricker were used in 1984, 1987, 1989 and 2002. That effect has not been adjusted for. However, the error in an absolute estimate comes primarily from the estimation of suitable habitat area for extrapolation. It may be advisable, for similar work in the future, to incorporate data on sediment type as well as depth to refine the estimate of habitat area for these species. I have used the overall mean CPUE to estimate biomass. A depth stratified estimator is more appropriate when species depth distribution changes significantly over time. However, the depth distribution for these species was remarkably consistent over time. That is because most of these species are dependent on food in the sediments in which they reside and the benthos is relatively static over time (if pollution is not a factor). Finally, I have used my experience in considering these estimates to be reliable. This comes as the result of 30 years of research and more than 20

surveys conducted and it is not objective or quantifiable. It is intangible and many scientists will be sceptical of it. However I would suggest that as we move to more complicated methods the probability of error may increase if we fail to incorporate pragmatic knowledge. It is only by conducting surveys and interacting with resource users that this type of knowledge is gained.

The investigation of the effect of fishing rates on a simulated population is also troublesome. The dynamic, stochastic nature of life history characteristics is not easy to capture. Similarly, the underlying stock recruitment relationship which heavily influences population numbers in age structured simulations is usually blurred. However, the shorter lifespan of many of the flatfish species does make them more amenable to simulation than long lived species. A modern management strategy evaluation (MSE) should be done as soon as possible for flatfish species. Yield management strategies for species with a short turnover time may not be that complex. Maximum yield is strongly determined by growth and reproductive parameters (maturity/fecundity and stock recruitment constants). Natural mortality rates, especially in older age groups, could vary widely without affecting the basic harvest strategy. The best strategy when fishing rate can be varied with age may be to harvest the initial age groups at a higher rate than the other age groups. When this cannot be controlled the best strategy may be periodic harvests or a fixed harvest rate strategy. All of this can be tested with an MSE.

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Table 1. Values used for (j indexes age) for population simulations for Dover Sole, English Sole, Rock Sole and Petrale Sole.

Species			Age 4	5	6	7	8	9	10	11	12	13	14	15	16
Dover Sole	M_j	Natural mortality rate	-	-	-	-	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	w_j	weight at age (kg)	-	-	-	-	0.506	0.590	0.672	0.752	0.828	0.900	0.968	1.030	1.088
	l_j	length at age (cm)	-	-	-	-	37.4	39.3	40.9	42.4	43.8	44.9	46.0	46.9	47.7
	m_j	proportion mature	-	-	-	-	0.816	0.907	0.952	0.974	0.985	0.991	1.000	1.000	1.000
English Sole	M_j	Natural mortality rate	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	-	-	-
	w_j	weight at age (kg)	0.316	0.447	0.568	0.673	0.762	0.834	0.891	0.937	0.973	1.000	-	-	-
	l_j	length at age (cm)	33.1	37.0	40.0	42.3	44.0	45.3	46.3	47.0	47.6	48.0	-	-	-
	m_j	proportion mature	0.484	0.905	0.982	0.995	0.998	0.999	1.000	1.000	1.000	1.000	-	-	-
Rock Sole	M_j	Natural mortality rate	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	-	-	-
	w_j	weight at age (kg)	0.306	0.465	0.634	0.793	0.948	1.081	1.208	1.308	1.404	1.484	-	-	-
	l_j	length at age (cm)	30.3	34.8	38.4	41.4	43.9	45.9	47.6	48.9	50.0	50.9	-	-	-
	m_j	proportion mature	0.300	0.500	0.900	1.000	1.000	1.000	1.000	1.000	1.000	1.000	-	-	-
Petrale Sole	M_j	Natural mortality rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	w_j	weight at age (kg)	0.318	0.504	0.713	0.932	1.151	1.362	1.562	1.745	1.912	2.062	2.195	2.312	2.415
	l_j	length at age (cm)	298.8	343.0	380.3	412.0	438.7	461.4	480.6	496.8	510.5	522.1	531.9	540.2	547.3
	m_j	proportion mature	0.220	0.630	0.880	0.960	0.980	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 1 cont'd.

Species			Age 17	18	19	20	21	22	23	24	25	26	27	28	29	30
Dover Sole	M_j	Natural mortality rate	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	w_j	weight at age (kg)	1.142	1.191	1.236	1.276	1.313	1.347	1.377	1.404	1.410	1.420	1.430	1.440	1.450	1.460
	l_j	length at age (cm)	48.5	49.1	49.7	50.2	50.7	51.1	51.4	51.8						
	m_j	proportion mature	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
English Sole	M_j	Natural mortality rate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	w_j	weight at age (kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	l_j	length at age (cm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	m_j	proportion mature	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rock Sole	M_j	Natural mortality rate	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	w_j	weight at age (kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	l_j	length at age (cm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	m_j	proportion mature	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petrale Sole	M_j	Natural mortality rate	0.2	0.2	0.2	0.2	-	-	-	-	-	-	-	-	-	-
	w_j	weight at age (kg)	2.504	2.581	2.648	2.705	-	-	-	-	-	-	-	-	-	-
	l_j	length at age (cm)	553.2	558.3	562.5	566.1	-	-	-	-	-	-	-	-	-	-
	m_j	proportion mature	1.000	1.000	1.000	1.000	-	-	-	-	-	-	-	-	-	-

Table 2. Biomass estimates and associated statistics for flatfish species in Hecate Strait using data for all depths

Species	Year	mean ln(CPUE)	$mean_b$	st. dev.	var.	s.e.	c.v.	90% lci	90% uci	biomass doors(t)	90% lci	90% uci	biomass net(t)	90% lci	90% uci
Pacific Sanddab	1984	2.977	19.627	4.094	0.129	16.761	0.204	14.948	25.367	3126	745	914	3262	778	954
Pacific Sanddab	1987	2.925	18.629	5.979	0.189	35.748	0.307	12.751	27.146	2967	936	1356	3096	977	1415
Pacific Sanddab	1989	2.912	18.389	4.305	0.136	18.533	0.228	13.751	24.742	2928	739	1012	3056	771	1056
Pacific Sanddab	1991	3.221	25.042	8.583	0.271	73.668	0.326	16.317	38.363	3988	1389	2121	4162	1450	2214
Pacific Sanddab	1993	2.896	18.108	6.363	0.201	40.488	0.334	11.923	27.762	2884	985	1537	3009	1028	1604
Pacific Sanddab	1995	2.565	13.000	3.475	0.110	12.076	0.259	9.474	17.877	2070	562	777	2161	586	811
Pacific Sanddab	1996	2.475	11.883	3.070	0.097	9.425	0.251	8.665	16.310	1892	512	705	1975	535	736
Pacific Sanddab	1998	3.405	30.115	9.698	0.307	94.051	0.308	20.893	43.861	4796	1469	2189	5005	1533	2285
Pacific Sanddab	2000	3.405	30.112	8.744	0.277	76.458	0.280	21.098	43.397	4795	1436	2115	5005	1498	2208
Pacific Sanddab	2002	3.445	31.355	9.791	0.310	95.864	0.299	21.299	45.907	4993	1601	2317	5211	1671	2418
Pacific Sanddab	2003	3.338	28.158	11.213	0.355	125.731	0.373	17.777	44.667	4484	1653	2629	4680	1725	2744
Arrowtooth Flounder	1984	4.350	77.516	4.094	0.129	16.761	0.204	56.714	107.443	12344	3313	4766	12883	3457	4974
Arrowtooth Flounder	1987	4.711	111.172	42.952	1.358	1844.874	0.364	72.028	170.681	17703	6233	9476	18476	6506	9890
Arrowtooth Flounder	1989	5.290	198.375	60.985	1.929	3719.170	0.295	138.733	283.733	31590	9498	13593	32969	9912	14186
Arrowtooth Flounder	1991	5.238	188.242	43.230	1.367	1868.833	0.224	141.984	251.124	29977	7366	10013	31285	7688	10451
Arrowtooth Flounder	1993	3.938	51.309	15.292	0.484	233.845	0.287	36.016	74.984	8171	2435	3770	8527	2542	3935
Arrowtooth Flounder	1995	4.352	77.663	21.045	0.666	442.892	0.262	55.160	106.355	12367	3584	4569	12907	3740	4769
Arrowtooth Flounder	1996	4.133	62.339	17.840	0.564	318.266	0.276	44.362	87.913	9927	2863	4072	10361	2988	4250
Arrowtooth Flounder	1998	4.906	135.044	33.645	1.064	1131.986	0.242	100.203	181.146	21505	5548	7341	22444	5790	7662
Arrowtooth Flounder	2000	4.528	92.596	27.457	0.868	753.887	0.285	65.187	130.004	14745	4365	5957	15389	4555	6217
Arrowtooth Flounder	2002	4.855	128.374	33.430	1.057	1117.565	0.252	93.853	176.286	20443	5497	7630	21335	5737	7963
Arrowtooth Flounder	2003	4.910	135.601	33.638	1.064	1131.515	0.241	98.690	184.952	21594	5878	7859	22537	6135	8202
Petrale Sole	1984	2.316	10.130	1.592	0.050	2.534	0.155	8.318	12.239	1613	289	336	1684	301	351
Petrale Sole	1987	1.579	4.852	0.639	0.020	0.408	0.131	4.093	5.755	773	121	144	806	126	150
Petrale Sole	1989	2.332	10.302	1.659	0.052	2.752	0.159	8.456	12.622	1641	294	369	1712	307	386
Petrale Sole	1991	2.118	8.317	2.613	0.083	6.828	0.302	5.889	11.941	1324	387	577	1382	404	602
Petrale Sole	1993	1.771	5.877	0.986	0.031	0.972	0.166	4.789	7.261	936	173	220	977	181	230
Petrale Sole	1995	1.554	4.729	0.747	0.024	0.558	0.156	3.917	5.756	753	129	163	786	135	171

Species	Year	mean ln(CPUE)	$mean_b$	st. dev.	var.	s.e.	c.v.	90% lci	90% uci	biomass doors(t)	90% lci	90% uci	biomass net(t)	90% lci	90% uci
Petrale Sole	1996	1.515	4.550	0.981	0.031	0.962	0.211	3.499	6.006	725	167	232	756	175	242
Petrale Sole	1998	1.920	6.823	1.702	0.054	2.897	0.243	5.067	9.202	1086	280	379	1134	292	395
Petrale Sole	2000	2.214	9.151	1.178	0.037	1.388	0.128	7.825	10.825	1457	211	267	1521	220	278
Petrale Sole	2002	2.153	8.607	1.585	0.050	2.512	0.181	6.913	10.831	1371	270	354	1431	282	370
Petrale Sole	2003	2.108	8.230	2.010	0.064	4.040	0.238	6.168	11.147	1311	328	464	1368	343	485
Rex Sole	1984	3.354	28.615	4.583	0.145	21.004	0.158	23.242	34.766	4557	856	980	4756	893	1022
Rex Sole	1987	3.136	23.005	6.089	0.193	37.076	0.256	16.600	32.047	3663	1020	1440	3823	1065	1503
Rex Sole	1989	3.803	44.856	10.186	0.322	103.755	0.222	33.803	60.288	7143	1760	2457	7455	1837	2565
Rex Sole	1991	4.175	65.018	11.313	0.358	127.984	0.171	51.523	80.792	10354	2149	2512	10806	2243	2622
Rex Sole	1993	3.478	32.408	7.862	0.249	61.811	0.236	24.375	43.317	5161	1279	1737	5386	1335	1813
Rex Sole	1995	3.841	46.565	10.354	0.327	107.205	0.217	35.420	61.147	7415	1775	2322	7739	1852	2423
Rex Sole	1996	3.726	41.528	8.603	0.272	74.012	0.203	31.976	53.821	6613	1521	1958	6902	1587	2043
Rex Sole	1998	3.997	54.411	13.766	0.435	189.503	0.246	40.347	76.014	8665	2240	3440	9043	2337	3590
Rex Sole	2000	4.186	65.787	14.023	0.443	196.645	0.209	51.017	85.307	10476	2352	3108	10934	2455	3244
Rex Sole	2002	4.160	64.086	14.593	0.461	212.956	0.222	48.505	85.289	10205	2481	3376	10651	2590	3524
Rex Sole	2003	4.063	58.128	13.274	0.420	176.199	0.223	43.991	77.350	9257	2251	3061	9661	2350	3195
Flathead Sole	1984	2.298	9.957	1.975	0.062	3.901	0.195	7.786	12.884	1586	346	466	1655	361	486
Flathead Sole	1987	2.674	14.493	4.308	0.136	18.559	0.286	10.100	21.037	2308	700	1042	2409	730	1088
Flathead Sole	1989	2.781	16.129	3.424	0.108	11.724	0.208	12.141	21.016	2568	635	778	2681	663	812
Flathead Sole	1991	2.170	8.754	1.913	0.060	3.660	0.214	6.628	11.273	1394	339	401	1455	353	419
Flathead Sole	1993	2.638	13.980	4.499	0.142	20.241	0.308	9.800	20.403	2226	666	1023	2323	695	1068
Flathead Sole	1995	2.610	13.599	3.342	0.106	11.169	0.239	10.193	18.532	2165	542	786	2260	566	820
Flathead Sole	1996	2.420	11.244	3.268	0.103	10.680	0.280	8.057	16.088	1791	508	771	1869	530	805
Flathead Sole	1998	2.626	13.823	4.743	0.150	22.496	0.326	9.197	21.073	2201	737	1154	2297	769	1205
Flathead Sole	2000	2.899	18.147	5.265	0.166	27.720	0.280	12.794	25.912	2890	853	1237	3016	890	1290
Flathead Sole	2002	2.806	16.536	4.402	0.139	19.378	0.258	11.961	23.011	2633	729	1031	2748	760	1076
Flathead Sole	2003	3.261	26.086	7.269	0.230	52.838	0.269	18.695	36.809	4154	1177	1708	4335	1228	1782
Butter Sole	1984	2.321	10.185	3.776	0.119	14.258	0.351	6.897	15.552	1622	523	855	1693	546	892
Butter Sole	1987	2.277	9.745	17.717	0.560	313.892	1.150	3.003	30.896	1552	1074	3368	1620	1121	3515
Butter Sole	1989	3.220	25.027	22.253	0.704	495.196	0.727	11.349	58.682	3985	2178	5359	4159	2273	5593
Butter Sole	1991	2.503	12.222	6.112	0.193	37.357	0.456	7.309	21.520	1946	782	1481	2031	816	1545

Species	Year	mean ln(CPUE)	$mean_b$	st. dev.	var.	s.e.	c.v.	90% lci	90% uci	biomass doors(t)	90% lci	90% uci	biomass net(t)	90% lci	90% uci
Butter Sole	1993	2.607	13.559	3.930	0.124	15.445	0.279	9.690	18.999	2159	616	866	2254	643	904
Butter Sole	1995	2.249	9.475	3.063	0.097	9.382	0.309	6.680	14.016	1509	445	723	1575	464	755
Butter Sole	1996	2.161	8.683	3.361	0.106	11.296	0.365	5.671	13.570	1383	480	778	1443	501	812
Butter Sole	1998	1.910	6.756	3.582	0.113	12.831	0.481	3.885	11.877	1076	457	815	1123	477	851
Butter Sole	2000	1.811	6.117	1.511	0.048	2.283	0.240	4.575	8.294	974	246	347	1017	256	362
Butter Sole	2002	2.329	10.273	3.373	0.107	11.377	0.313	6.956	15.184	1636	528	782	1707	551	816
Butter Sole	2003	2.511	12.319	3.237	0.102	10.478	0.255	9.173	16.955	1962	501	738	2047	523	771
Rock Sole	1984	2.762	15.834	2.082	0.066	4.335	0.130	13.421	18.633	2522	384	446	2632	401	465
Rock Sole	1987	3.139	23.081	4.152	0.131	17.239	0.177	18.476	28.633	3675	733	884	3836	765	923
Rock Sole	1989	3.833	46.201	11.007	0.348	121.154	0.232	34.109	61.796	7357	1926	2484	7678	2010	2592
Rock Sole	1991	3.511	33.467	5.977	0.189	35.725	0.176	26.745	41.988	5329	1071	1357	5562	1117	1416
Rock Sole	1993	3.933	51.063	9.449	0.299	89.284	0.182	40.388	64.155	8131	1700	2085	8487	1774	2176
Rock Sole	1995	3.432	30.950	5.058	0.160	25.583	0.161	25.102	38.074	4929	931	1134	5144	972	1184
Rock Sole	1996	3.964	52.685	9.841	0.311	96.845	0.184	41.817	66.295	8390	1731	2167	8756	1806	2262
Rock Sole	1998	3.698	40.384	11.140	0.352	124.100	0.267	28.855	56.026	6431	1836	2491	6712	1916	2600
Rock Sole	2000	3.531	34.160	6.230	0.197	38.813	0.179	27.018	42.630	5440	1137	1349	5677	1187	1408
Rock Sole	2002	3.557	35.061	5.816	0.184	33.826	0.164	28.314	43.098	5583	1075	1280	5827	1121	1336
Rock Sole	2003	3.630	37.720	9.036	0.286	81.649	0.233	28.291	50.509	6007	1502	2037	6269	1567	2126
Slender Sole	1984	1.334	3.796	0.739	0.023	0.546	0.191	3.003	4.767	604	126	155	631	132	161
Slender Sole	1987	1.566	4.789	0.920	0.029	0.846	0.189	3.811	6.131	763	156	214	796	162	223
Slender Sole	1989	2.252	9.509	4.186	0.132	17.523	0.408	5.798	15.941	1514	591	1024	1580	617	1069
Slender Sole	1991	1.486	4.420	0.969	0.031	0.939	0.214	3.390	5.762	704	164	214	735	171	223
Slender Sole	1993	3.411	30.283	10.115	0.320	102.313	0.318	19.538	46.852	4822	1711	2639	5033	1786	2754
Slender Sole	1995	1.846	6.334	1.606	0.051	2.579	0.246	4.661	8.764	1009	266	387	1053	278	404
Slender Sole	1996	1.377	3.964	1.454	0.046	2.114	0.348	2.661	5.973	631	207	320	659	217	334
Slender Sole	1998	2.116	8.300	3.831	0.121	14.677	0.424	4.839	14.100	1322	551	924	1379	575	964
Slender Sole	2000	2.375	10.746	3.904	0.123	15.241	0.344	7.057	16.705	1711	587	949	1786	613	990
Slender Sole	2002	1.940	6.962	1.310	0.041	1.716	0.185	5.477	8.805	1109	236	293	1157	247	306
Slender Sole	2003	2.438	11.450	4.379	0.138	19.176	0.360	7.240	18.223	1823	670	1079	1903	700	1126
Dover Sole	1984	3.370	29.076	7.522	0.238	56.580	0.251	21.606	40.536	4630	1190	1825	4832	1242	1905
Dover Sole	1987	3.995	54.338	17.910	0.566	320.768	0.314	36.887	81.502	8653	2779	4326	9031	2900	4515

Species	Year	mean ln(CPUE)	$mean_b$	st. dev.	var.	s.e.	c.v.	90% lci	90% uci	biomass doors(t)	90% lci	90% uci	biomass net(t)	90% lci	90% uci
Dover Sole	1989	4.386	80.338	24.076	0.761	579.654	0.288	56.185	117.169	12793	3846	5865	13352	4014	6121
Dover Sole	1991	3.604	36.733	8.517	0.269	72.539	0.226	27.801	48.758	5850	1422	1915	6105	1485	1999
Dover Sole	1993	3.547	34.708	10.312	0.326	106.337	0.286	24.620	49.515	5527	1606	2358	5768	1677	2461
Dover Sole	1995	3.019	20.464	5.070	0.160	25.705	0.241	14.898	27.551	3259	886	1129	3401	925	1178
Dover Sole	1996	3.003	20.136	4.764	0.151	22.696	0.231	14.937	27.077	3207	828	1105	3347	864	1154
Dover Sole	1998	3.612	37.054	11.493	0.363	132.089	0.298	26.109	53.827	5901	1743	2671	6158	1819	2788
Dover Sole	2000	3.775	43.592	11.654	0.369	135.816	0.259	31.699	59.612	6942	1894	2551	7245	1977	2662
Dover Sole	2002	4.288	72.814	18.791	0.594	353.102	0.250	52.741	99.153	11595	3197	4194	12102	3336	4377
Dover Sole	2003	4.332	76.116	18.013	0.570	324.468	0.230	56.358	101.316	12121	3146	4013	12650	3284	4188
English Sole	1984	3.901	49.451	7.099	0.224	50.396	0.142	41.574	59.335	7875	1254	1574	8219	1309	1643
English Sole	1987	3.870	47.925	10.194	0.322	103.918	0.208	36.775	62.681	7632	1776	2350	7965	1853	2452
English Sole	1989	4.056	57.737	14.091	0.446	198.556	0.237	42.536	76.832	9194	2421	3041	9596	2526	3174
English Sole	1991	4.379	79.731	12.142	0.384	147.428	0.151	65.948	96.716	12697	2195	2705	13251	2291	2823
English Sole	1993	4.284	72.500	14.790	0.468	218.744	0.200	55.477	93.832	11545	2711	3397	12049	2829	3545
English Sole	1995	3.521	33.816	6.714	0.212	45.078	0.195	26.200	43.395	5385	1213	1525	5620	1266	1592
English Sole	1996	3.569	35.483	7.217	0.228	52.085	0.199	27.520	45.512	5650	1268	1597	5897	1323	1667
English Sole	1998	3.779	43.791	10.698	0.338	114.447	0.238	32.426	58.106	6973	1810	2280	7278	1889	2379
English Sole	2000	4.097	60.151	10.795	0.341	116.532	0.177	48.432	75.146	9579	1866	2388	9997	1948	2492
English Sole	2002	4.081	59.229	11.524	0.364	132.803	0.191	46.459	75.565	9432	2034	2601	9844	2122	2715
English Sole	2003	4.323	75.431	16.559	0.524	274.200	0.215	57.344	99.193	12012	2880	3784	12536	3006	3949
Starry Flounder	1984	2.410	11.129	8.129	0.257	66.081	0.612	4.767	25.886	1772	1013	2350	1850	1057	2453
Starry Flounder	1987	2.341	10.392	1.049	0.033	1.100	0.100	9.009	12.012	1655	220	258	1727	230	269
Starry Flounder	1989	2.771	15.969	7.645	0.242	58.446	0.442	9.947	27.163	2543	959	1783	2654	1001	1860
Starry Flounder	1991	2.242	9.409	2.701	0.085	7.295	0.276	6.450	13.501	1498	471	652	1564	492	680
Starry Flounder	1993	3.504	33.235	8.571	0.271	73.462	0.250	23.930	45.822	5293	1482	2004	5524	1547	2092
Starry Flounder	1995	2.528	12.531	5.107	0.161	26.081	0.378	7.552	20.296	1995	793	1236	2083	828	1290
Starry Flounder	1996	1.949	7.020	4.113	0.130	16.917	0.520	3.684	13.192	1118	531	983	1167	554	1026
Starry Flounder	1998	2.557	12.896	4.208	0.133	17.707	0.312	8.944	18.439	2054	629	883	2143	657	921
Starry Flounder	2000	2.331	10.286	6.841	0.216	46.799	0.580	5.424	19.910	1638	774	1533	1709	808	1600
Starry Flounder	2002	2.638	13.987	4.364	0.138	19.044	0.299	9.589	20.384	2227	700	1019	2325	731	1063
Starry Flounder	2003	2.835	17.027	15.894	0.503	252.619	0.781	8.718	34.259	2711	1323	2744	2830	1381	2864

Species	Year	mean ln(CPUE)	$mean_b$	st. dev.	var.	s.e.	c.v.	90% lci	90% uci	biomass doors(t)	90% lci	90% uci	biomass net(t)	90% lci	90% uci
Curlfin Sole	1984	1.395	4.035	0.566	0.018	0.320	0.139	3.413	4.786	642	99	120	671	103	125
Curlfin Sole	1987	1.350	3.856	0.808	0.026	0.653	0.205	3.003	4.926	614	136	170	641	142	178
Curlfin Sole	1989	1.537	4.649	0.730	0.023	0.533	0.155	3.847	5.690	740	128	166	773	133	173
Curlfin Sole	1991	1.231	3.424	1.203	0.038	1.447	0.335	2.381	5.206	545	166	284	569	173	296
Curlfin Sole	1993	1.752	5.768	0.959	0.030	0.920	0.164	4.735	7.134	919	165	218	959	172	227
Curlfin Sole	1995	1.293	3.643	0.617	0.020	0.381	0.167	2.976	4.497	580	106	136	605	111	142
Curlfin Sole	1996	1.079	2.943	0.287	0.009	0.082	0.097	2.577	3.339	469	58	63	489	61	66
Curlfin Sole	1998	1.231	3.426	0.525	0.017	0.276	0.152	2.828	4.119	546	95	110	569	99	115
Curlfin Sole	2000	1.802	6.059	1.183	0.037	1.399	0.192	4.727	7.780	965	212	274	1007	221	286
Curlfin Sole	2002	1.477	4.378	0.779	0.025	0.607	0.175	3.521	5.459	697	137	172	728	142	180
Curlfin Sole	2003	1.611	5.008	1.244	0.039	1.548	0.242	3.777	6.819	797	196	288	832	205	301
Sand Sole	1984	1.732	5.652	1.446	0.046	2.091	0.248	4.160	7.693	900	238	325	939	248	339
Sand Sole	1987	1.759	5.808	1.835	0.058	3.367	0.303	4.023	8.616	925	284	447	965	297	467
Sand Sole	1989	2.512	12.330	3.300	0.104	10.890	0.259	8.987	17.209	1964	532	777	2049	556	811
Sand Sole	1991	2.329	10.267	2.728	0.086	7.442	0.258	7.501	14.059	1635	441	604	1706	460	630
Sand Sole	1993	3.153	23.400	6.000	0.190	36.000	0.249	16.806	32.734	3726	1050	1486	3889	1096	1551
Sand Sole	1995	2.233	9.323	1.647	0.052	2.713	0.174	7.494	11.693	1485	291	377	1550	304	394
Sand Sole	1996	1.779	5.923	1.102	0.035	1.214	0.183	4.728	7.523	943	190	255	984	199	266
Sand Sole	1998	1.637	5.139	1.307	0.041	1.708	0.247	3.797	6.937	818	214	286	854	223	299
Sand Sole	2000	2.180	8.843	2.305	0.073	5.313	0.253	6.440	12.015	1408	383	505	1470	399	527
Sand Sole	2002	2.527	12.522	2.365	0.075	5.593	0.186	9.909	15.916	1994	416	540	2081	434	564
Sand Sole	2003	3.109	22.392	5.725	0.181	32.776	0.248	16.427	30.753	3566	950	1331	3721	991	1390

Table 3. Biomass estimates and associated statistics for flatfish species in Hecate Strait using data for the 90% confidence interval of the species depth range.

Species	Year	mean ln(CPUE)	$Mean_b$	stdev	var	s.e.	c.v.	lci	uci	Biomass doors (t)	90% lci	90% uci	Biomass net (t)	90% lci	90% uci
Pacific Sanddab	1984	3.089	21.961	0.204	0.042	0.006	0.215	16.837	28.389	3497	816	1024	3650	852	1068
Pacific Sanddab	1987	2.965	19.402	0.312	0.097	0.010	0.323	12.988	28.680	3090	1021	1478	3225	1066	1542
Pacific Sanddab	1989	2.921	18.563	0.249	0.062	0.008	0.261	13.578	25.391	2956	794	1087	3085	828	1135
Pacific Sanddab	1991	3.243	25.600	0.321	0.103	0.010	0.330	17.024	38.303	4077	1366	2023	4255	1425	2111
Pacific Sanddab	1993	2.896	18.108	0.319	0.102	0.010	0.334	11.923	27.762	2884	985	1537	3009	1028	1604
Pacific Sanddab	1995	2.665	14.368	0.264	0.070	0.008	0.273	10.325	20.301	2288	644	945	2388	672	986
Pacific Sanddab	1996	2.528	12.524	0.261	0.068	0.008	0.264	8.789	17.456	1994	595	785	2081	621	820
Pacific Sanddab	1998	3.464	31.943	0.343	0.118	0.011	0.361	20.577	49.873	5087	1810	2855	5309	1889	2980
Pacific Sanddab	2000	3.468	32.086	0.267	0.071	0.008	0.272	22.883	45.347	5109	1465	2112	5333	1529	2204
Pacific Sanddab	2002	3.492	32.863	0.299	0.089	0.009	0.299	22.491	48.233	5233	1652	2448	5462	1724	2554
Pacific Sanddab	2003	3.386	29.544	0.366	0.134	0.012	0.372	18.457	47.356	4706	1767	2835	4912	1844	2958
Arrowtooth Flounder	1984	4.147	63.275	0.262	0.069	0.008	0.267	45.466	88.994	10076	2836	4096	10516	2960	4274
Arrowtooth Flounder	1987	4.317	74.984	0.426	0.181	0.013	0.436	43.781	128.510	11941	4969	8524	12462	5186	8896
Arrowtooth Flounder	1989	5.015	150.656	0.347	0.120	0.011	0.347	95.203	238.588	23991	8831	14003	25039	9216	14614
Arrowtooth Flounder	1991	5.248	190.260	0.234	0.055	0.007	0.232	143.204	256.270	30298	7493	10512	31621	7821	10971
Arrowtooth Flounder	1993	3.871	47.973	0.280	0.078	0.009	0.284	33.350	68.829	7639	2329	3321	7973	2430	3466
Arrowtooth Flounder	1995	4.297	73.507	0.274	0.075	0.009	0.274	51.422	101.968	11706	3517	4532	12217	3670	4730
Arrowtooth Flounder	1996	4.124	61.822	0.275	0.076	0.009	0.279	43.355	89.450	9845	2941	4400	10275	3069	4592
Arrowtooth Flounder	1998	5.023	151.913	0.291	0.085	0.009	0.301	103.974	218.919	24191	7634	10670	25247	7967	11136
Arrowtooth Flounder	2000	4.685	108.310	0.281	0.079	0.009	0.287	74.925	154.137	17248	5316	7298	18001	5548	7616
Arrowtooth Flounder	2002	4.972	144.332	0.269	0.072	0.009	0.277	101.895	207.011	22984	6758	9981	23988	7053	10417
Arrowtooth Flounder	2003	4.885	132.344	0.259	0.067	0.008	0.262	94.892	184.870	21075	5964	8364	21995	6224	8730
Petrale Sole	1984	2.295	9.922	0.161	0.026	0.005	0.165	8.121	12.340	1580	287	385	1649	299	402
Petrale Sole	1987	1.606	4.981	0.136	0.018	0.004	0.137	4.167	5.948	793	130	154	828	135	161
Petrale Sole	1989	2.426	11.315	0.174	0.030	0.006	0.179	9.188	14.196	1802	339	459	1881	354	479
Petrale Sole	1991	2.221	9.217	0.281	0.079	0.009	0.308	6.534	13.587	1468	427	696	1532	446	726
Petrale Sole	1993	1.733	5.655	0.172	0.030	0.005	0.176	4.532	7.051	901	179	222	940	187	232
Petrale Sole	1995	1.554	4.729	0.153	0.023	0.005	0.156	3.917	5.756	753	129	163	786	135	171
Petrale Sole	1996	1.553	4.727	0.209	0.044	0.007	0.216	3.618	6.172	753	177	230	786	184	240

Species	Year	mean ln(CPUE)	Mean$_b$	stdev	var	s.e.	c.v.	lci	uci	Biomass doors (t)	90% lci	90% uci	Biomass net (t)	90% lci	90% uci
Petrale Sole	1998	2.169	8.751	0.210	0.044	0.007	0.218	6.683	11.393	1393	329	421	1454	344	439
Petrale Sole	2000	2.214	9.148	0.130	0.017	0.004	0.131	7.792	10.882	1457	216	276	1520	225	288
Petrale Sole	2002	2.230	9.299	0.177	0.031	0.006	0.180	7.334	11.663	1481	313	376	1545	327	393
Petrale Sole	2003	2.160	8.675	0.258	0.067	0.008	0.268	6.259	12.135	1381	385	551	1442	401	575
Rex Sole	1984	3.337	28.135	0.163	0.027	0.005	0.163	22.641	34.810	4480	875	1063	4676	913	1109
Rex Sole	1987	2.936	18.844	0.272	0.074	0.009	0.276	13.320	26.556	3001	880	1228	3132	918	1282
Rex Sole	1989	3.632	37.780	0.233	0.054	0.007	0.237	28.437	52.354	6016	1488	2321	6279	1553	2422
Rex Sole	1991	4.140	62.802	0.173	0.030	0.005	0.173	50.086	78.651	10001	2025	2524	10438	2113	2634
Rex Sole	1993	3.526	33.993	0.226	0.051	0.007	0.235	25.669	45.403	5413	1325	1817	5649	1383	1896
Rex Sole	1995	3.883	48.590	0.208	0.043	0.007	0.206	36.352	62.820	7738	1949	2266	8075	2034	2365
Rex Sole	1996	3.779	43.758	0.204	0.042	0.006	0.203	33.033	56.917	6968	1708	2095	7272	1783	2187
Rex Sole	1998	4.171	64.802	0.274	0.075	0.009	0.277	45.717	92.169	10319	3039	4358	10770	3172	4548
Rex Sole	2000	4.282	72.365	0.203	0.041	0.006	0.203	55.912	92.601	11524	2620	3222	12027	2735	3363
Rex Sole	2002	4.415	82.663	0.231	0.053	0.007	0.233	61.131	111.002	13164	3429	4513	13738	3579	4710
Rex Sole	2003	4.106	60.728	0.230	0.053	0.007	0.233	45.351	82.926	9671	2449	3535	10093	2556	3689
Flathead Sole	1984	2.335	10.334	0.215	0.046	0.007	0.217	7.820	13.676	1646	400	532	1718	418	555
Flathead Sole	1987	2.273	9.713	0.317	0.100	0.010	0.328	6.497	14.599	1547	512	778	1614	535	812
Flathead Sole	1989	2.598	13.437	0.270	0.073	0.009	0.273	9.414	19.236	2140	641	923	2233	669	964
Flathead Sole	1991	2.170	8.754	0.213	0.045	0.007	0.214	6.628	11.273	1394	339	401	1455	353	419
Flathead Sole	1993	2.638	13.980	0.290	0.084	0.009	0.308	9.800	20.403	2226	666	1023	2323	695	1068
Flathead Sole	1995	2.610	13.599	0.235	0.055	0.007	0.239	10.193	18.532	2165	542	786	2260	566	820
Flathead Sole	1996	2.420	11.244	0.270	0.073	0.009	0.280	8.057	16.088	1791	508	771	1869	530	805
Flathead Sole	1998	2.700	14.879	0.459	0.211	0.015	0.478	8.457	26.904	2369	1023	1915	2473	1067	1999
Flathead Sole	2000	2.921	18.553	0.266	0.071	0.008	0.275	13.298	26.045	2955	837	1193	3084	873	1245
Flathead Sole	2002	2.979	19.668	0.274	0.075	0.009	0.280	13.796	28.444	3132	935	1397	3269	976	1458
Flathead Sole	2003	3.314	27.489	0.265	0.070	0.008	0.273	19.440	38.567	4377	1282	1764	4569	1338	1841
Butter Sole	1984	2.321	10.185	0.325	0.106	0.010	0.344	6.830	15.498	1622	534	846	1693	558	883
Butter Sole	1987	2.277	9.745	0.937	0.878	0.030	1.150	3.003	30.896	1552	1074	3368	1620	1121	3515
Butter Sole	1989	3.044	20.984	0.667	0.445	0.021	0.876	9.129	50.786	3342	1888	4746	3488	1970	4953
Butter Sole	1991	2.866	17.567	0.433	0.187	0.014	0.479	10.190	31.491	2797	1175	2217	2920	1226	2314
Butter Sole	1993	2.654	14.215	0.264	0.070	0.008	0.270	10.216	19.826	2264	637	893	2363	665	932
Butter Sole	1995	2.245	9.437	0.315	0.099	0.010	0.329	6.298	14.076	1503	500	739	1568	522	771

Species	Year	mean ln(CPUE)	$Mean_b$	stdev	var	s.e.	c.v.	lci	uci	Biomass doors (t)	90% lci	90% uci	Biomass net (t)	90% lci	90% uci
Butter Sole	1996	2.307	10.042	0.368	0.135	0.012	0.406	6.360	16.740	1599	586	1067	1669	612	1113
Butter Sole	1998	1.513	4.538	0.365	0.133	0.012	0.408	2.878	7.372	723	264	451	754	276	471
Butter Sole	2000	1.861	6.428	0.234	0.055	0.007	0.245	4.811	8.722	1024	257	365	1068	269	381
Butter Sole	2002	2.329	10.273	0.303	0.092	0.010	0.313	6.956	15.184	1636	528	782	1707	551	816
Butter Sole	2003	2.517	12.397	0.251	0.063	0.008	0.255	8.940	17.105	1974	550	750	2060	574	782
Rock Sole	1984	2.858	17.419	0.140	0.020	0.004	0.142	14.670	20.981	2774	438	567	2895	457	592
Rock Sole	1987	3.116	22.548	0.183	0.033	0.006	0.186	17.747	28.568	3591	765	959	3747	798	1001
Rock Sole	1989	3.887	48.768	0.222	0.049	0.007	0.225	36.890	64.645	7766	1891	2528	8105	1974	2639
Rock Sole	1991	3.509	33.419	0.182	0.033	0.006	0.181	26.130	41.913	5322	1161	1352	5554	1211	1412
Rock Sole	1993	3.960	52.465	0.186	0.035	0.006	0.187	41.575	67.431	8355	1734	2383	8719	1810	2487
Rock Sole	1995	3.449	31.484	0.177	0.031	0.006	0.176	24.965	39.347	5014	1038	1252	5233	1084	1307
Rock Sole	1996	3.973	53.149	0.183	0.033	0.006	0.183	42.192	67.405	8464	1745	2270	8833	1821	2369
Rock Sole	1998	3.007	20.229	0.507	0.257	0.016	0.594	10.695	38.738	3221	1518	2947	3362	1585	3076
Rock Sole	2000	3.564	35.292	0.199	0.040	0.006	0.200	27.385	45.271	5620	1259	1589	5865	1314	1658
Rock Sole	2002	3.523	33.874	0.180	0.032	0.006	0.181	26.824	42.806	5394	1123	1422	5630	1172	1484
Rock Sole	2003	3.573	35.635	0.256	0.066	0.008	0.257	25.547	49.296	5675	1607	2175	5923	1677	2270
Slender Sole	1984	1.333	3.793	0.187	0.035	0.006	0.195	3.003	4.767	604	126	155	630	131	162
Slender Sole	1987	1.300	3.671	0.205	0.042	0.006	0.215	2.815	4.767	585	136	175	610	142	182
Slender Sole	1989	2.582	13.230	0.454	0.206	0.014	0.453	6.921	23.722	2107	1005	1671	2199	1049	1744
Slender Sole	1991	1.486	4.420	0.209	0.044	0.007	0.214	3.390	5.762	704	164	214	735	171	223
Slender Sole	1993	3.411	30.283	0.320	0.102	0.010	0.318	19.538	46.852	4822	1711	2639	5033	1786	2754
Slender Sole	1995	1.941	6.969	0.245	0.060	0.008	0.248	5.061	9.554	1110	304	412	1158	317	430
Slender Sole	1996	1.377	3.964	0.320	0.102	0.010	0.348	2.661	5.973	631	207	320	659	217	334
Slender Sole	1998	1.986	7.286	0.456	0.208	0.014	0.486	4.068	13.091	1160	512	924	1211	535	965
Slender Sole	2000	2.178	8.831	0.295	0.087	0.009	0.304	6.080	13.042	1406	438	670	1468	457	700
Slender Sole	2002	2.055	7.810	0.201	0.040	0.006	0.203	6.097	10.049	1244	273	357	1298	285	372
Slender Sole	2003	2.438	11.450	0.349	0.122	0.011	0.360	7.240	18.223	1823	670	1079	1903	700	1126
Dover Sole	1984	3.373	29.179	0.262	0.069	0.008	0.272	21.100	41.043	4647	1286	1889	4849	1343	1972
Dover Sole	1987	3.734	41.843	0.392	0.154	0.012	0.399	24.574	70.169	6663	2750	4511	6954	2870	4708
Dover Sole	1989	4.149	63.379	0.340	0.116	0.011	0.350	40.756	98.309	10093	3603	5562	10533	3760	5805
Dover Sole	1991	3.551	34.853	0.239	0.057	0.008	0.240	25.421	47.063	5550	1502	1944	5792	1568	2029
Dover Sole	1993	3.621	37.390	0.283	0.080	0.009	0.294	26.241	53.496	5954	1775	2565	6214	1853	2677

Species	Year	mean ln(CPUE)	$Mean_b$	stdev	var	s.e.	c.v.	lci	uci	Biomass doors (t)	90% lci	90% uci	Biomass net (t)	90% lci	90% uci
Dover Sole	1995	3.018	20.460	0.236	0.056	0.007	0.241	15.289	27.514	3258	823	1123	3400	859	1172
Dover Sole	1996	3.032	20.741	0.235	0.055	0.007	0.238	15.418	28.092	3303	848	1171	3447	885	1222
Dover Sole	1998	4.063	58.154	0.318	0.101	0.010	0.335	39.181	89.005	9261	3021	4913	9665	3153	5127
Dover Sole	2000	3.772	43.458	0.248	0.062	0.008	0.250	31.667	59.074	6920	1878	2487	7223	1960	2595
Dover Sole	2002	4.365	78.627	0.251	0.063	0.008	0.257	57.019	108.847	12521	3441	4812	13068	3591	5023
Dover Sole	2003	4.325	75.600	0.230	0.053	0.007	0.229	56.398	102.073	12039	3058	4216	12565	3191	4400
English Sole	1984	3.941	51.461	0.154	0.024	0.005	0.155	42.454	62.418	8195	1434	1745	8553	1497	1821
English Sole	1987	3.902	49.480	0.213	0.045	0.007	0.217	38.016	65.744	7879	1826	2590	8223	1905	2703
English Sole	1989	4.237	69.208	0.239	0.057	0.008	0.246	51.642	94.887	11021	2797	4089	11502	2919	4268
English Sole	1991	4.392	80.769	0.164	0.027	0.005	0.163	65.223	99.644	12862	2476	3006	13424	2584	3137
English Sole	1993	4.337	76.464	0.205	0.042	0.006	0.207	59.064	98.443	12177	2771	3500	12708	2892	3653
English Sole	1995	3.587	36.113	0.203	0.041	0.006	0.205	27.664	46.520	5751	1345	1657	6002	1404	1730
English Sole	1996	3.644	38.247	0.198	0.039	0.006	0.203	30.093	50.158	6091	1299	1897	6357	1355	1980
English Sole	1998	3.736	41.937	0.264	0.070	0.008	0.269	29.773	58.277	6678	1937	2602	6970	2022	2716
English Sole	2000	4.167	64.549	0.173	0.030	0.005	0.173	51.784	79.018	10279	2033	2304	10728	2122	2405
English Sole	2002	4.214	67.632	0.197	0.039	0.006	0.198	52.852	86.535	10770	2354	3010	11240	2456	3142
English Sole	2003	4.302	73.820	0.223	0.050	0.007	0.229	56.620	98.556	11755	2739	3939	12269	2859	4111
Starry Flounder	1984	3.065	21.426	0.400	0.160	0.013	0.398	12.012	38.000	3412	1499	2639	3561	1565	2754
Starry Flounder	1987	2.341	10.392	0.100	0.010	0.003	0.100	9.009	12.012	1655	220	258	1727	230	269
Starry Flounder	1989	2.771	15.969	0.388	0.151	0.012	0.442	9.947	27.163	2543	959	1783	2654	1001	1860
Starry Flounder	1991	2.242	9.409	0.291	0.085	0.009	0.276	6.450	13.501	1498	471	652	1564	492	680
Starry Flounder	1993	3.265	26.175	0.201	0.040	0.006	0.208	19.831	34.888	4168	1010	1387	4350	1054	1448
Starry Flounder	1995	1.714	5.550	0.413	0.171	0.013	0.380	3.212	9.391	884	372	612	922	389	638
Starry Flounder	1996	1.949	7.020	0.486	0.236	0.015	0.520	3.684	13.192	1118	531	983	1167	554	1026
Starry Flounder	1998	2.192	8.951	0.078	0.006	0.002	0.078	8.000	10.000	1425	151	167	1488	158	174
Starry Flounder	2000	2.331	10.286	0.507	0.257	0.016	0.580	5.424	19.910	1638	774	1533	1709	808	1600
Starry Flounder	2002	2.638	13.987	0.293	0.086	0.009	0.299	9.589	20.384	2227	700	1019	2325	731	1063
Starry Flounder	2003	2.988	19.837	0.678	0.460	0.021	0.933	8.619	43.905	3159	1786	3833	3297	1864	4000
Curlfin Sole	1984	1.439	4.218	0.159	0.025	0.005	0.165	3.452	5.224	672	122	160	701	127	167
Curlfin Sole	1987	1.350	3.856	0.199	0.040	0.006	0.205	3.003	4.926	614	136	170	641	142	178
Curlfin Sole	1989	1.537	4.649	0.152	0.023	0.005	0.155	3.847	5.690	740	128	166	773	133	173
Curlfin Sole	1991	1.231	3.424	0.298	0.089	0.009	0.335	2.381	5.206	545	166	284	569	173	296

Species	Year	mean ln(CPUE)	$Mean_b$	stdev	var	s.e.	c.v.	lci	uci	Biomass doors (t)	90% lci	90% uci	Biomass net (t)	90% lci	90% uci
Curlfin Sole	1993	1.807	6.092	0.176	0.031	0.006	0.181	4.865	7.620	970	195	243	1012	204	254
Curlfin Sole	1995	1.293	3.643	0.163	0.027	0.005	0.167	2.976	4.497	580	106	136	605	111	142
Curlfin Sole	1996	1.079	2.943	0.097	0.009	0.003	0.097	2.577	3.339	469	58	63	489	61	66
Curlfin Sole	1998	1.418	4.129	0.221	0.049	0.007	0.214	3.129	5.419	657	159	205	686	166	214
Curlfin Sole	2000	1.786	5.966	0.190	0.036	0.006	0.194	4.681	7.719	950	205	279	992	214	291
Curlfin Sole	2002	1.513	4.539	0.202	0.041	0.006	0.207	3.551	5.974	723	157	228	754	164	238
Curlfin Sole	2003	1.611	5.008	0.229	0.052	0.007	0.242	3.777	6.819	797	196	288	832	205	301
Sand Sole	1984	1.732	5.652	0.239	0.057	0.008	0.248	4.160	7.693	900	238	325	939	248	339
Sand Sole	1987	1.828	6.224	0.307	0.094	0.010	0.311	4.155	9.410	991	330	507	1034	344	529
Sand Sole	1989	2.410	11.139	0.249	0.062	0.008	0.256	8.098	15.209	1774	484	648	1851	506	676
Sand Sole	1991	2.179	8.840	0.220	0.048	0.007	0.220	6.637	11.729	1408	351	460	1469	366	480
Sand Sole	1993	3.246	25.681	0.243	0.059	0.008	0.245	18.544	34.967	4089	1136	1479	4268	1186	1543
Sand Sole	1995	2.230	9.304	0.172	0.030	0.005	0.173	7.445	11.583	1482	296	363	1546	309	379
Sand Sole	1996	1.774	5.895	0.188	0.035	0.006	0.192	4.671	7.509	939	195	257	980	203	268
Sand Sole	1998	1.292	3.642	0.326	0.106	0.010	0.343	2.572	5.253	580	170	257	605	178	268
Sand Sole	2000	2.238	9.372	0.251	0.063	0.008	0.258	6.851	13.139	1492	401	600	1558	419	626
Sand Sole	2002	2.488	12.033	0.201	0.040	0.006	0.202	9.260	15.620	1916	442	571	2000	461	596
Sand Sole	2003	2.976	19.606	0.280	0.078	0.009	0.290	13.894	28.469	3122	909	1411	3258	949	1473

Table 4. Summary of the mean, minimum and maximum biomass estimates for data from all depths compared with data from the 90% confidence interval of the depth distribution for each species.

	All depths Biomass			Selected depths[1] Biomass		
Species	Mean	Min	Max	Mean	Min	Max
Pacific Sanddab	3693	1975	5211	3883	2081	5462
Arrowtooth Flounder	19010	8527	32969	18121	7973	31621
Petrale Sole	1232	756	1712	1306	786	1881
Rex Sole	7923	3823	10934	8377	3132	13738
Flathead Sole	2459	1455	4335	2442	1455	4569
Butter Sole	1879	1017	4159	1901	754	3488
Rock Sole	6053	2632	8756	5806	2895	8833
Slender Sole	1519	631	5033	1537	610	5033
Dover Sole	7636	3347	13352	7610	3400	13068
English Sole	9296	5620	13251	9816	6002	13424
Starry Flounder	2325	1167	5524	2251	922	4350
Curlfin Sole	713	489	1007	732	489	1012
Sand Sole	1837	854	3889	1773	605	4268

[1] Depth range inclusive of the 90 percent confidence interval of the species depth distribution.

Table 5. Calculated exploitation rates for flatfish species in Hecate Strait in 2003.

Year	Species	Trawl catch (t)	Biomass (net) (t)	Exploitation rate
2003	Pacific Sanddab	20	4680	0.0043
2003	Arrowtooth Flounder	1117	22537	0.0496
2003	Petrale Sole	52	1368	0.0380
2003	Rex Sole	269	9661	0.0278
2003	Flathead Sole	57	4335	0.0131
2003	Butter Sole	3	2047	0.0015
2003	Rock Sole	756	6269	0.1206
2003	Slender Sole	2	1903	0.0011
2003	Dover Sole	852	12650	0.0674
2003	English Sole	540	12536	0.0431
2003	Starry Flounder	19	2830	0.0067
2003	Curlfin Sole	6	832	0.0072
2003	Sand Sole	47	3721	0.0126

Table 6. Model cases for the estimation of the stock recruitment relationship for Dover Sole, English Sole, Rock Sole and Petrale Sole.

Beverton-Holt model

Case	Species/Stock	Data/Method
1	WCVI Dover Sole	Oregon (scaled to B.C. tonnage)
2	WCVI Dover Sole	B.C. surplus production estimates (2000-2008)
3	WCVI Dover Sole	Oregon SR data (scaled) Recruitment variation +/-10%
4	WCVI Dover Sole	Oregon SR data (scaled) Recruitment variation +/- 30%
5	WCVI Dover Sole	Random rec.
6	Hecate St. English Sole	Catch-age model
7	Hecate St. English Sole	CPUE (scaled)
8	Hecate St. Rock Sole	catch-age model
9	Hecate St. Rock Sole	CPUE (scaled)
10	WCVI Petrale Sole	Catch-age model

Ricker model

Case	Species/Stock	Data/Method
11	WCVI Dover Sole	Oregon scaled
12	WCVI Dover Sole	B.C.
13	Hecate St. English Sole	Catch-Age model
14	Hecate St. English Sole	CPUE (scaled)
15	Hecate St. English Sole	Stochastic +/- 10%
16	Hecate St. English Sole	Stochastic +/- 30%
17	Hecate St. English Sole	Random rec.
18	Hecate St. Rock Sole	Catch-age model
19	Hecate St. Rock Sole	CPUE (scaled)
20	Hecate St. Rock Sole	Stochastic +/- 10%
21	Hecate St. Rock Sole	Stochastic +/- 30%
22	Hecate St. Rock Sole	Random rec.
23	WCVI Petrale Sole	Catch-age model
24	WCVI Petrale Sole	Stochastic +/- 10%
25	WCVI Petrale Sole	Stochastic +/- 30%

Table 7. Spawning stock biomass per recruit, yield per recruit and survival ratios estimated for flatfish species from population simulations.

Ricker stock recruitment relationship

							Steepness			
Case	Species	N	SS	MSE	a	b	h^1	h^2	B_0	SPB0
1	Dover Sole	46	44876195	975569	0.941	0.000126	0.807	0.785	13975	13544
2	Dover Sole	9	10624997	1180555	0.726	0.000172	0.636	0.597	8235	7959
3	Dover Sole	46	45176471	982097	0.941	0.000126	0.807	0.775	13872	13411
4	Dover Sole	46	57524443	1250531	0.941	0.000126	0.807	0.732	13188	12849
5	Dover Sole	46	64087817	1393213	n/a	n/a	n/a	n/a	15350	14962
6	English Sole	55	45374755	824996	1.755	0.000168	0.632	0.592	8837	8095
7	English Sole	34	45440718	1336492	2.106	0.000137	0.676	0.641	11609	10609
8	Rock Sole	54	109278013	2023667	1.340	0.000122	0.561	0.533	11788	10038
9	Rock Sole	24	84705107	3529379	2.069	0.000246	0.762	0.740	7829	6646
10	Petrale Sole	26	6914803	265954	0.780	0.000175	0.752	0.597	8547	7818

Beverton-Holt stock recruitment relationship

							Steepness			
Case	Species	N	SS	MSE	a	b	h^1	h^2	B_0	Initial Spawning biomass
11	Dover Sole	46	45362895	986150	0.488	0.000330	0.761	0.751	16843	16323
12	Dover Sole	9	10857421	1206380	0.722	0.000641	0.672	0.670	8299	8042
13	English Sole	55	43627487	793227	0.430	0.000173	0.592	0.566	11413	10457
14	English Sole	34	45276663	1331667	0.400	0.000108	0.587	0.562	16719	15275
15	English Sole	55	45101715	820031	0.430	0.000173	0.592	0.583	12488	11406
16	English Sole	55	73475699	1335922	0.430	0.000173	0.592	0.554	10560	9839
17	English Sole	55	105818873	1923980	n/a	n/a	n/a	n/a	9115	7992
18	Rock Sole	54	75988620	1407197	0.519	0.000178	0.556	0.546	13002	11077
19	Rock Sole	24	83604733	3483531	0.120	0.000320	0.840	0.838	8704	7415
20	Rock Sole	54	81326155	1506040	0.519	0.000178	0.556	0.550	13359	11302
21	Rock Sole	54	108817507	2015139	0.519	0.000178	0.556	0.544	12615	10957
22	Rock Sole	54	196207150	3633466	n/a	n/a	n/a	n/a	9493	7828
23	Petrale Sole	26	6556281	252165	0.442	0.000599	0.823	0.749	8821	8068
24	Petrale Sole	26	7577056	291425	0.442	0.000599	0.823	0.750	8912	8146
25	Petrale Sole	26	13261131	510043	n/a	n/a	n/a	n/a	6525	6087

Yellow highlight indicates the stock-recruit model with the best fit

Red numbers indicate the case with the best fit overall

[1] Computed from simulation model

[2] Computed from stock recruitment relationship without error

Table 8. Spawning stock biomass per recruit, yield per recruit and survival ratios estimated for Dover Sole from population simulations with fishing mortality between 0.0 and 2.5.

F	Spawning stock biomass per recruit (kg)	Yield per recruit (kg)	Biomass per recruit (kg)	Slope of the yield per recruit curve	Survival ratio	Spawning per recruit (SPR)	1/SPR
0.00	5.875	0.000	6.062	5.629	1.000	0.170	1.000
0.05	4.233	0.215	4.412	2.784	0.820	0.236	0.721
0.10	3.243	0.325	3.415	1.503	0.670	0.308	0.552
0.15	2.606	0.386	2.771	0.877	0.540	0.384	0.443
0.20	2.171	0.422	2.330	0.547	0.430	0.461	0.370
0.25	1.861	0.446	2.014	0.359	0.340	0.537	0.317
0.30	1.630	0.461	1.779	0.246	0.260	0.614	0.277
0.35	1.453	0.472	1.598	0.174	0.190	0.688	0.247
0.40	1.313	0.480	1.454	0.127	0.130	0.761	0.224
0.45	1.201	0.485	1.339	0.094	0.080	0.832	0.204
0.50	1.109	0.489	1.244	0.079	0.030	0.901	0.189
0.55	1.037	0.495	1.169	0.134	0.000	0.964	0.177
0.60	0.981	0.501	1.110	0.108	0.000	1.020	0.167
0.65	0.931	0.506	1.058	0.083	0.000	1.074	0.158
0.70	0.887	0.509	1.012	0.064	0.000	1.128	0.151
0.75	0.848	0.512	0.971	0.049	0.000	1.180	0.144
0.80	0.813	0.515	0.934	0.037	0.000	1.231	0.138
0.85	0.781	0.516	0.901	0.027	0.000	1.280	0.133
0.90	0.753	0.517	0.872	0.019	0.000	1.328	0.128
0.95	0.728	0.518	0.845	0.013	0.000	1.374	0.124
1.00	0.705	0.519	0.821	0.009	0.000	1.419	0.120
1.05	0.684	0.519	0.799	0.005	0.000	1.462	0.116
1.10	0.665	0.519	0.778	0.002	0.000	1.504	0.113
1.15	0.648	0.519	0.760	-0.001	0.000	1.544	0.110
1.20	0.632	0.519	0.743	-0.003	0.000	1.583	0.108
1.25	0.617	0.519	0.728	-0.004	0.000	1.620	0.105
1.30	0.604	0.519	0.713	-0.005	0.000	1.656	0.103
1.35	0.592	0.519	0.700	-0.006	0.000	1.690	0.101
1.40	0.580	0.518	0.688	-0.007	0.000	1.723	0.099
1.45	0.570	0.518	0.677	-0.007	0.000	1.755	0.097
1.50	0.560	0.518	0.666	-0.008	0.000	1.785	0.095
1.55	0.551	0.517	0.656	-0.008	0.000	1.814	0.094
1.60	0.543	0.517	0.647	-0.008	0.000	1.842	0.092
1.65	0.535	0.516	0.639	-0.008	0.000	1.869	0.091
1.70	0.528	0.516	0.631	-0.008	0.000	1.895	0.090

Table 8. cont'd

F	Spawning stock biomass per recruit (kg)	Yield per recruit (kg)	Biomass per recruit (kg)	Slope of the yield per recruit curve	Survival ratio	Spawning per recruit (SPR)	1/SPR
1.75	0.521	0.516	0.624	-0.008	0.000	1.919	0.089
1.80	0.515	0.515	0.617	-0.008	0.000	1.943	0.088
1.85	0.509	0.515	0.611	-0.008	0.000	1.965	0.087
1.90	0.503	0.514	0.605	-0.007	0.000	1.987	0.086
1.95	0.498	0.514	0.599	-0.007	0.000	2.007	0.085
2.00	0.493	0.514	0.594	-0.007	0.000	2.027	0.084
2.05	0.489	0.513	0.589	-0.007	0.000	2.045	0.083
2.10	0.485	0.513	0.585	-0.007	0.000	2.063	0.082
2.15	0.481	0.513	0.580	-0.007	0.000	2.080	0.082
2.20	0.477	0.512	0.576	-0.006	0.000	2.097	0.081
2.25	0.473	0.512	0.572	-0.005	0.000	2.112	0.081
2.30	0.470	0.512	0.569	-0.005	0.000	2.127	0.080
2.35	0.467	0.512	0.565	-0.004	0.000	2.141	0.080
2.40	0.464	0.511	0.562	-0.005	0.000	2.154	0.079
2.45	0.462	0.511	0.559	-0.005	0.000	2.167	0.079
2.50	0.459	0.511	0.556		0.000	2.179	0.078

Table 9. Spawning stock biomass per recruit, yield per recruit and survival ratios estimated for English Sole from population simulations with fishing mortality between 0.0 and 2.5.

F	Spawning stock biomass per recruit (kg)	Yield per recruit (kg)	Biomass per recruit (kg)	Slope of the yield per recruit curve	Survival ratio	Spawning per recruit (SPR)	1/SPR
0.00	2.240	0.000	2.352	2.263	1.000	0.446	1.000
0.05	1.864	0.098	2.002	1.547	0.832	0.537	1.202
0.10	1.574	0.165	1.731	1.073	0.703	0.635	1.423
0.15	1.348	0.212	1.519	0.754	0.602	0.742	1.662
0.20	1.169	0.245	1.349	0.538	0.522	0.855	1.916
0.25	1.026	0.268	1.213	0.390	0.458	0.975	2.183
0.30	0.910	0.286	1.102	0.286	0.406	1.099	2.461
0.35	0.815	0.298	1.010	0.213	0.364	1.227	2.748
0.40	0.737	0.308	0.934	0.161	0.329	1.358	3.041
0.45	0.671	0.315	0.870	0.123	0.299	1.491	3.339
0.50	0.615	0.321	0.815	0.096	0.275	1.625	3.641
0.55	0.568	0.325	0.768	0.077	0.254	1.761	3.944
0.60	0.528	0.329	0.728	0.064	0.236	1.896	4.246
0.65	0.493	0.332	0.694	0.054	0.220	2.029	4.544
0.70	0.463	0.334	0.664	0.048	0.207	2.158	4.833
0.75	0.438	0.337	0.638	0.043	0.196	2.281	5.109
0.80	0.417	0.339	0.615	0.039	0.186	2.398	5.373
0.85	0.398	0.340	0.595	0.034	0.178	2.511	5.625
0.90	0.382	0.342	0.576	0.029	0.170	2.620	5.869
0.95	0.367	0.343	0.560	0.023	0.164	2.727	6.108
1.00	0.353	0.344	0.545	0.018	0.158	2.832	6.345
1.05	0.340	0.345	0.531	0.014	0.152	2.937	6.579
1.10	0.329	0.346	0.518	0.010	0.147	3.041	6.812
1.15	0.318	0.346	0.507	0.006	0.142	3.144	7.042
1.20	0.308	0.347	0.496	0.003	0.138	3.246	7.271
1.25	0.299	0.347	0.486	0.001	0.133	3.347	7.497
1.30	0.290	0.347	0.477	-0.002	0.130	3.447	7.721
1.35	0.282	0.347	0.468	-0.003	0.126	3.545	7.941
1.40	0.275	0.346	0.460	-0.005	0.123	3.642	8.159
1.45	0.268	0.346	0.452	-0.006	0.119	3.738	8.373
1.50	0.261	0.346	0.445	-0.007	0.117	3.832	8.584
1.55	0.255	0.345	0.438	-0.008	0.114	3.924	8.790
1.60	0.249	0.345	0.432	-0.009	0.111	4.015	8.993
1.65	0.244	0.344	0.426	-0.009	0.109	4.103	9.192
1.70	0.239	0.344	0.421	-0.010	0.107	4.190	9.386

Table 9 cont'd.

F	Spawning stock biomass per recruit (kg)	Yield per recruit (kg)	Biomass per recruit (kg)	Slope of the yield per recruit curve	Survival ratio	Spawning per recruit (SPR)	1/SPR
1.75	0.234	0.344	0.416	-0.010	0.104	4.275	9.576
1.80	0.229	0.343	0.411	-0.010	0.102	4.358	9.761
1.85	0.225	0.343	0.406	-0.010	0.101	4.438	9.942
1.90	0.221	0.342	0.402	-0.010	0.099	4.517	10.118
1.95	0.218	0.342	0.398	-0.010	0.097	4.594	10.289
2.00	0.214	0.341	0.394	-0.010	0.096	4.668	10.456
2.05	0.211	0.341	0.391	-0.010	0.094	4.740	10.618
2.10	0.208	0.340	0.387	-0.010	0.093	4.811	10.776
2.15	0.205	0.340	0.384	-0.010	0.091	4.880	10.930
2.20	0.202	0.339	0.381	-0.009	0.090	4.946	11.079
2.25	0.200	0.339	0.379	-0.009	0.089	5.011	11.225
2.30	0.197	0.338	0.376	-0.009	0.088	5.074	11.365
2.35	0.195	0.338	0.373	-0.009	0.087	5.135	11.501
2.40	0.193	0.337	0.371	-0.008	0.086	5.193	11.633
2.45	0.190	0.337	0.369	-0.008	0.085	5.250	11.759
2.50	0.189	0.336	0.367		0.084	5.304	11.880

Table 10. Spawning stock biomass per recruit, yield per recruit and survival ratios estimated for Rock Sole from population simulations.

F	Spawning stock biomass per recruit (kg)	Yield per recruit (kg)	Biomass per recruit (kg)	Slope of the yield per recruit curve	Survival ratio	Spawning per recruit (SPR)	1/SPR
0.00	2.495	0.000	2.808	2.694	1.000	0.401	1.000
0.05	2.013	0.115	2.354	1.779	0.807	0.497	1.239
0.10	1.648	0.191	2.006	1.187	0.660	0.607	1.514
0.15	1.367	0.242	1.736	0.799	0.548	0.731	1.825
0.20	1.150	0.276	1.524	0.544	0.461	0.870	2.170
0.25	0.979	0.300	1.356	0.376	0.392	1.022	2.550
0.30	0.842	0.316	1.220	0.265	0.338	1.187	2.962
0.35	0.733	0.328	1.110	0.194	0.294	1.364	3.403
0.40	0.645	0.337	1.021	0.152	0.259	1.549	3.866
0.45	0.576	0.344	0.949	0.131	0.231	1.737	4.333
0.50	0.523	0.350	0.890	0.122	0.209	1.914	4.775
0.55	0.482	0.356	0.842	0.111	0.193	2.075	5.179
0.60	0.449	0.361	0.801	0.095	0.180	2.229	5.561
0.65	0.420	0.366	0.765	0.077	0.168	2.381	5.942
0.70	0.394	0.369	0.733	0.059	0.158	2.537	6.330
0.75	0.371	0.372	0.705	0.043	0.149	2.697	6.729
0.80	0.350	0.374	0.679	0.029	0.140	2.861	7.139
0.85	0.330	0.375	0.655	0.017	0.132	3.029	7.558
0.90	0.312	0.376	0.633	0.007	0.125	3.201	7.987
0.95	0.296	0.376	0.613	-0.001	0.119	3.376	8.424
1.00	0.281	0.376	0.594	-0.008	0.113	3.554	8.868
1.05	0.268	0.375	0.577	-0.013	0.107	3.734	9.318
1.10	0.255	0.374	0.561	-0.018	0.102	3.917	9.773
1.15	0.244	0.373	0.546	-0.022	0.098	4.101	10.233
1.20	0.233	0.372	0.533	-0.025	0.093	4.286	10.695
1.25	0.224	0.371	0.520	-0.027	0.090	4.472	11.160
1.30	0.215	0.369	0.508	-0.028	0.086	4.659	11.625
1.35	0.206	0.368	0.497	-0.030	0.083	4.845	12.090
1.40	0.199	0.367	0.487	-0.031	0.080	5.031	12.554
1.45	0.192	0.365	0.477	-0.031	0.077	5.216	13.016
1.50	0.185	0.363	0.468	-0.031	0.074	5.400	13.475
1.55	0.179	0.362	0.459	-0.031	0.072	5.582	13.929
1.60	0.174	0.360	0.451	-0.031	0.070	5.762	14.378
1.65	0.168	0.359	0.444	-0.031	0.067	5.940	14.822
1.70	0.164	0.357	0.437	-0.030	0.066	6.115	15.259

Table 10 cont'd.

F	Spawning stock biomass per recruit (kg)	Yield per recruit (kg)	Biomass per recruit (kg)	Slope of the yield per recruit curve	Survival ratio	Spawning per recruit (SPR)	1/SPR
1.75	0.159	0.356	0.431	-0.030	0.064	6.287	15.689
1.80	0.155	0.354	0.424	-0.029	0.062	6.456	16.111
1.85	0.151	0.353	0.419	-0.028	0.061	6.622	16.524
1.90	0.147	0.351	0.413	-0.028	0.059	6.784	16.929
1.95	0.144	0.350	0.408	-0.027	0.058	6.943	17.324
2.00	0.141	0.349	0.403	-0.026	0.056	7.097	17.710
2.05	0.138	0.347	0.399	-0.025	0.055	7.248	18.085
2.10	0.135	0.346	0.395	-0.024	0.054	7.394	18.450
2.15	0.133	0.345	0.391	-0.023	0.053	7.536	18.805
2.20	0.130	0.344	0.387	-0.022	0.052	7.674	19.149
2.25	0.128	0.343	0.383	-0.022	0.051	7.808	19.483
2.30	0.126	0.342	0.380	-0.021	0.050	7.937	19.806
2.35	0.124	0.341	0.377	-0.020	0.050	8.063	20.119
2.40	0.122	0.340	0.374	-0.019	0.049	8.184	20.422
2.45	0.120	0.339	0.371	-0.018	0.048	8.302	20.715
2.50	0.119	0.338	0.368		0.048	8.415	20.998

Table 11. Spawning stock biomass per recruit, yield per recruit and survival ratios estimated for Petrale Sole from population simulations.

F	Spawning stock biomass per recruit (kg)	Yield per recruit (kg)	Biomass per recruit (kg)	Slope of the yield per recruit curve	Survival ratio	Spawning per recruit (SPR)	1/SPR
0.00	5.234	0.000	5.723	5.350	1.000	0.191	1.000
0.05	3.788	0.208	4.259	2.723	0.724	0.264	1.382
0.10	2.842	0.314	3.297	1.394	0.543	0.352	1.842
0.15	2.201	0.368	2.641	0.704	0.420	0.454	2.378
0.20	1.751	0.395	2.178	0.337	0.335	0.571	2.989
0.25	1.426	0.407	1.841	0.137	0.272	0.701	3.671
0.30	1.184	0.412	1.588	0.028	0.226	0.844	4.419
0.35	1.001	0.412	1.394	-0.032	0.191	0.999	5.231
0.40	0.858	0.409	1.242	-0.065	0.164	1.166	6.104
0.45	0.744	0.406	1.120	-0.081	0.142	1.344	7.033
0.50	0.653	0.401	1.020	-0.089	0.125	1.532	8.016
0.55	0.578	0.397	0.938	-0.091	0.110	1.729	9.050
0.60	0.517	0.392	0.870	-0.090	0.099	1.935	10.13
0.65	0.465	0.388	0.812	-0.087	0.089	2.150	11.25
0.70	0.422	0.384	0.762	-0.083	0.081	2.372	12.41
0.75	0.384	0.380	0.720	-0.078	0.073	2.602	13.61
0.80	0.352	0.376	0.683	-0.074	0.067	2.837	14.84
0.85	0.325	0.372	0.650	-0.069	0.062	3.078	16.11
0.90	0.301	0.369	0.622	-0.064	0.057	3.324	17.39
0.95	0.280	0.366	0.597	-0.060	0.053	3.574	18.70
1.00	0.261	0.363	0.574	-0.056	0.050	3.827	20.03
1.05	0.245	0.360	0.554	-0.053	0.047	4.084	21.37
1.10	0.230	0.358	0.536	-0.049	0.044	4.342	22.72
1.15	0.217	0.355	0.520	-0.046	0.042	4.602	24.08
1.20	0.206	0.353	0.505	-0.043	0.039	4.863	25.45
1.25	0.195	0.351	0.492	-0.040	0.037	5.124	26.82
1.30	0.186	0.349	0.480	-0.037	0.035	5.385	28.18
1.35	0.177	0.347	0.469	-0.035	0.034	5.645	29.54
1.40	0.169	0.345	0.459	-0.033	0.032	5.904	30.90
1.45	0.162	0.344	0.449	-0.029	0.031	6.158	32.23
1.50	0.157	0.343	0.441	-0.021	0.030	6.370	33.34
1.55	0.154	0.342	0.434	-0.018	0.029	6.510	34.07
1.60	0.151	0.341	0.427	-0.018	0.029	6.631	34.71
1.65	0.148	0.340	0.421	-0.018	0.028	6.750	35.33
1.70	0.146	0.339	0.415	-0.017	0.028	6.867	35.94

Table 11 cont'd.

F	Spawning stock biomass per recruit (kg)	Yield per recruit (kg)	Biomass per recruit (kg)	Slope of the yield per recruit curve	Survival ratio	Spawning per recruit (SPR)	1/SPR
1.75	0.143	0.338	0.409	-0.017	0.027	6.982	36.543
1.80	0.141	0.337	0.404	-0.017	0.027	7.094	37.134
1.85	0.139	0.336	0.399	-0.016	0.027	7.205	37.713
1.90	0.137	0.336	0.395	-0.016	0.026	7.314	38.281
1.95	0.135	0.335	0.390	-0.015	0.026	7.420	38.837
2.00	0.133	0.334	0.386	-0.015	0.025	7.524	39.380
2.05	0.131	0.333	0.383	-0.014	0.025	7.625	39.911
2.10	0.129	0.333	0.379	-0.014	0.025	7.724	40.428
2.15	0.128	0.332	0.376	-0.013	0.024	7.820	40.933
2.20	0.126	0.331	0.373	-0.013	0.024	7.914	41.424
2.25	0.125	0.331	0.370	-0.012	0.024	8.005	41.901
2.30	0.124	0.330	0.367	-0.012	0.024	8.094	42.365
2.35	0.122	0.329	0.364	-0.011	0.023	8.180	42.816
2.40	0.121	0.329	0.362	-0.011	0.023	8.263	43.253
2.45	0.120	0.328	0.359	-0.010	0.023	8.344	43.676
2.50	0.119	0.328	0.357		0.023	8.423	44.086

Table 12. Reference points calculated for Dover Sole, English Sole, Rock Sole and Petrale Sole. The yellow highlight indicates the rates calculated from the stock recruitment model with the best fit.

Ricker stock recruitment relationship

Case	Species	$F_{0.1}$	F_{max}	F_{msy}	F_{high}	F_{rep}	F_{low}	$SPR_{50\%}$	$SPR_{40\%}$	$SPR_{35\%}$	$SPR_{30\%}$	$SPR_{20\%}$	F_{crash}
1	Dover Sole	0.20	1.14	0.20	0.04	0.11	0.20	0.12	0.18	0.22	0.27	0.46	0.92
2	Dover Sole	0.21	0.95	0.15	n/a	n/a	n/a	0.14	0.20	0.24	0.30	0.54	0.70
3	Dover Sole	0.22	1.01	0.20	0.03	0.09	0.18	0.13	0.19	0.23	0.29	0.52	0.92
4	Dover Sole	0.17	0.97	0.19	0.08	0.15	0.25	0.11	0.16	0.20	0.24	0.39	0.92
5	Dover Sole	0.17	0.35	0.36	n/a	n/a	n/a	0.12	0.17	0.20	0.25	0.39	n/a
6	English Sole	0.34	1.13	0.24	0.13	0.20	0.27	0.22	0.31	0.37	0.45	0.78	1.70
7	English Sole	0.34	1.24	0.29	0.29	0.35	0.55	0.22	0.31	0.37	0.45	0.74	2.05
8	Rock Sole	0.27	0.63	0.18	0.12	0.18	0.26	0.18	0.24	0.29	0.35	0.52	1.31
9	Rock Sole	0.29	1.02	0.27	0.03	0.09	0.33	0.18	0.25	0.29	0.36	0.58	1.97
10	Petrale Sole	0.17	0.63	0.16	0.06	0.09	0.18	0.11	0.16	0.19	0.23	0.34	0.75

Beverton-Holt stock recruitment relationship

Case	Species	$F_{0.1}$	F_{max}	F_{msy}	F_{high}	F_{rep}	F_{low}	$SPR_{50\%}$	$SPR_{40\%}$	$SPR_{35\%}$	$SPR_{30\%}$	$SPR_{20\%}$	F_{crash}
11	Dover Sole	0.20	2.44	0.23	0.04	0.11	0.20	0.12	0.18	0.22	0.27	0.46	1.81
12	Dover Sole	0.20	1.57	0.19	n/a	n/a	n/a	0.12	0.18	0.22	0.27	0.46	1.18
13	English Sole	0.34	1.27	0.23	0.14	0.20	0.28	0.22	0.31	0.37	0.44	0.73	2.15
14	English Sole	0.34	1.33	0.24	0.28	0.36	0.56	0.22	0.31	0.37	0.44	0.73	2.37
15	English Sole	0.34	1.21	0.26	0.13	0.20	0.27	0.21	0.30	0.37	0.44	0.71	2.15
16	English Sole	0.33	1.19	0.21	0.18	0.25	0.33	0.21	0.31	0.37	0.46	0.76	2.15
17	English Sole	0.32	0.93	n/a	n/a	n/a	n/a	0.21	0.30	0.37	0.46	0.77	n/a
18	Rock Sole	0.30	0.95	0.18	0.11	0.18	0.27	0.17	0.26	0.30	0.37	0.59	1.80
19	Rock Sole	0.27	0.58	0.33	0.04	0.10	0.33	0.18	0.24	0.29	0.34	0.51	5.43
20	Rock Sole	0.30	0.96	0.18	0.10	0.16	0.24	0.17	0.24	0.28	0.34	0.53	1.80
21	Rock Sole	0.30	0.93	0.17	0.23	0.30	0.39	0.31	0.39	0.44	0.51	0.76	1.80
22	Rock Sole	0.36	n/a	n/a	n/a	n/a	n/a	0.16	0.22	0.26	0.31	0.48	n/a
23	Petrale Sole	0.17	0.32	0.20	0.06	0.09	0.18	0.12	0.16	0.19	0.23	0.34	1.78
24	Petrale Sole	0.17	0.33	0.18	0.05	0.08	0.17	0.11	0.16	0.19	0.23	0.33	1.78
25	Petrale Sole	0.15	0.25	0.24	n/a	n/a	n/a	0.12	0.16	0.19	0.23	0.34	n/a

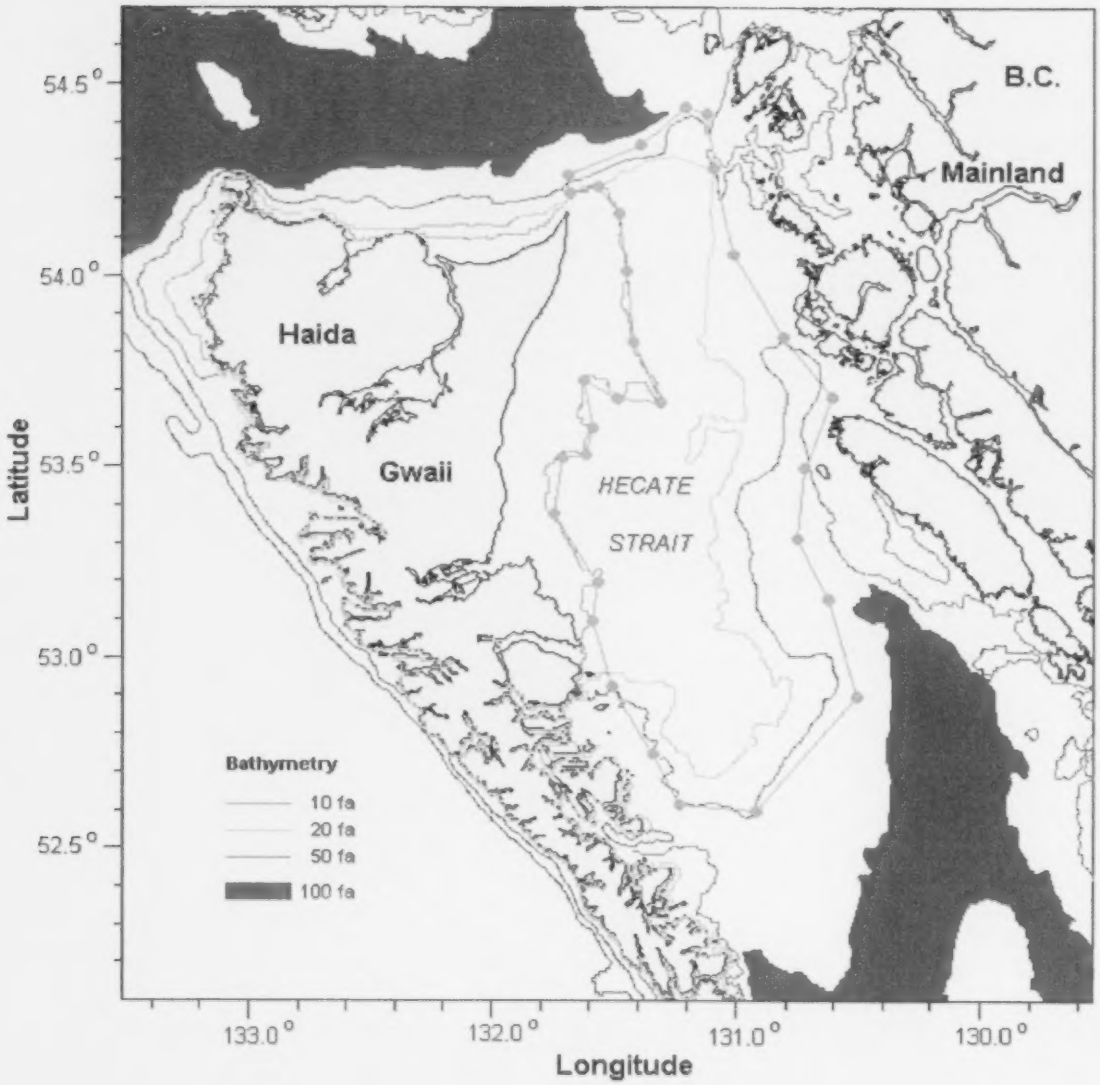


Figure 1. The study area, Hecate Strait, British Columbia where the Hecate Strait Assemblage bottom trawl surveys were conducted from 1984 to 2003. The red polygon contains, roughly, the area used for estimation of biomass.

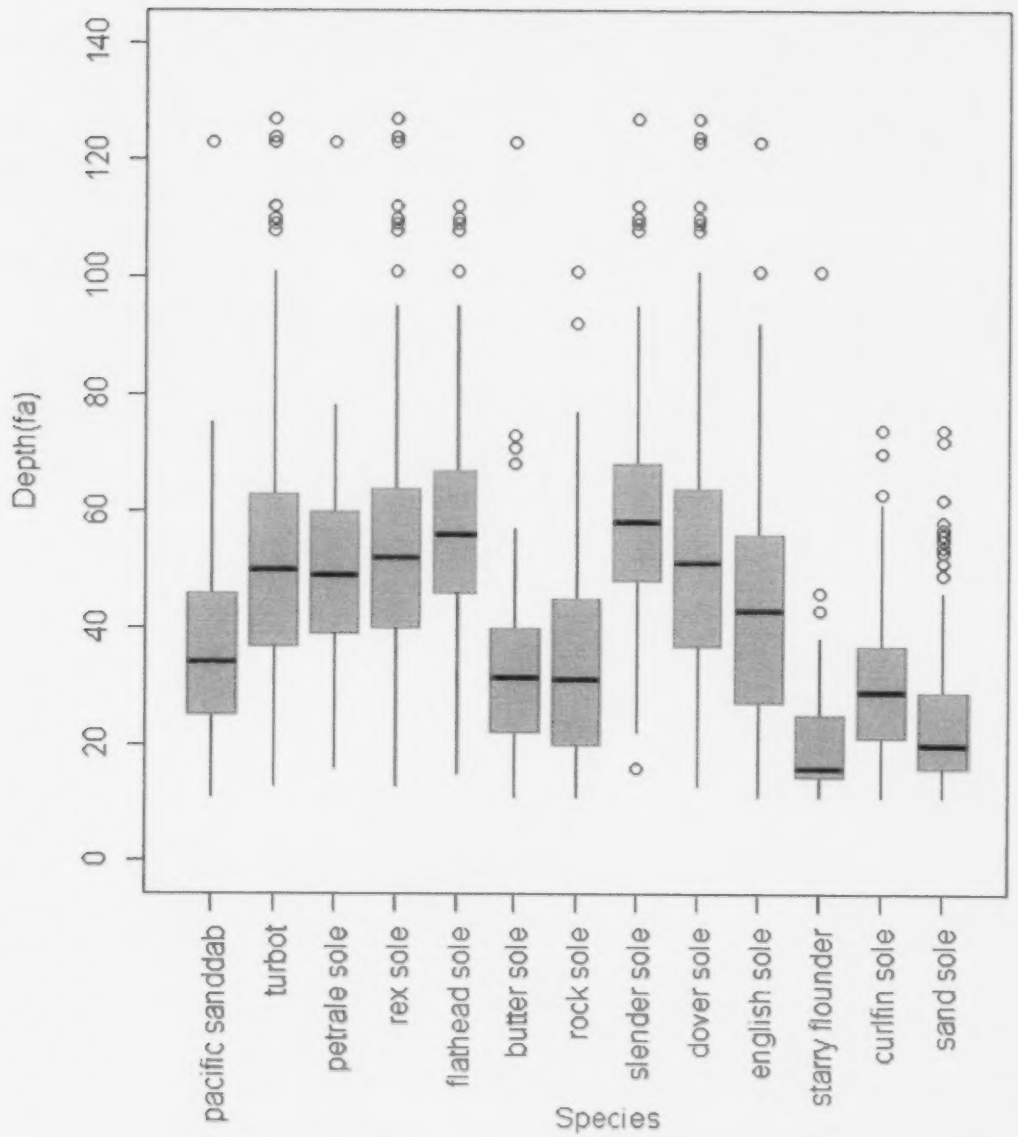


Figure 2. Depth distribution of flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003. The coloured box represents the first and third quartiles. The vertical lines represent 1.5 times the inter quartile range. The horizontal lines represent the median. The open circles represent data outliers.

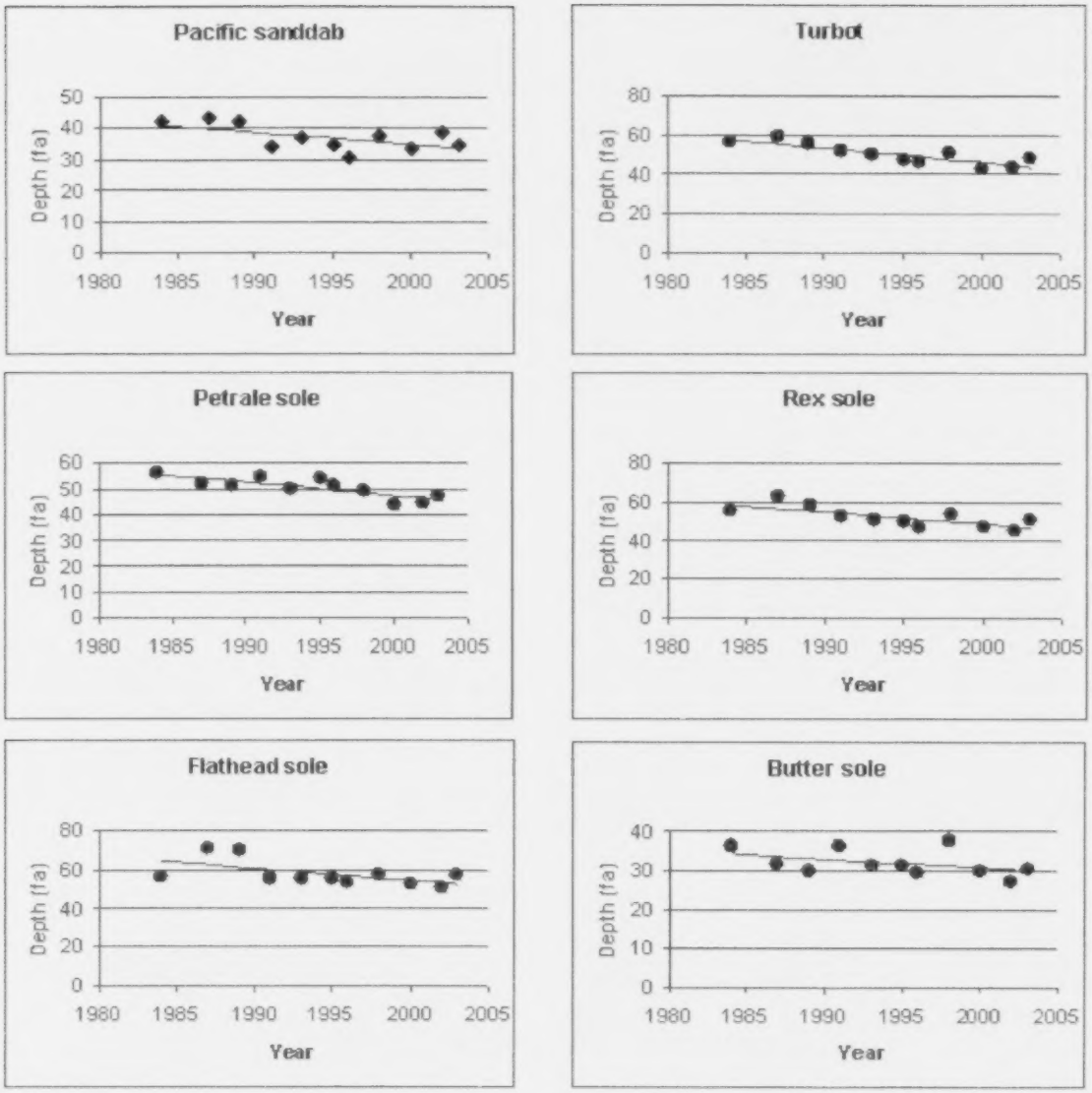
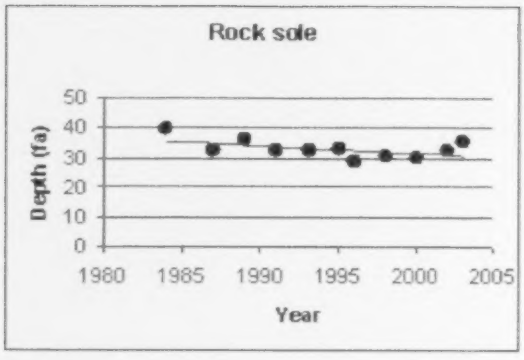
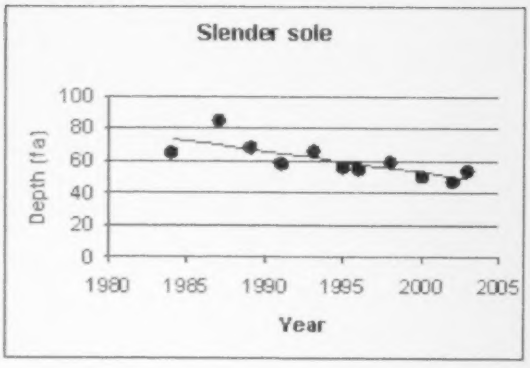
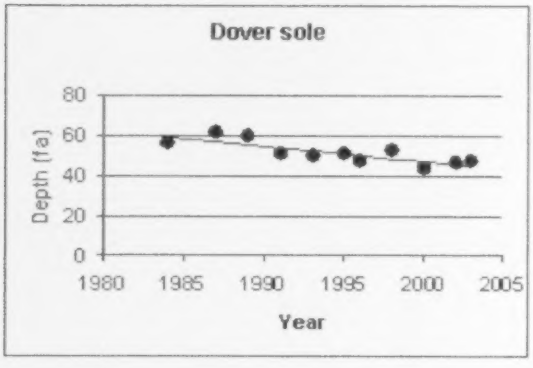
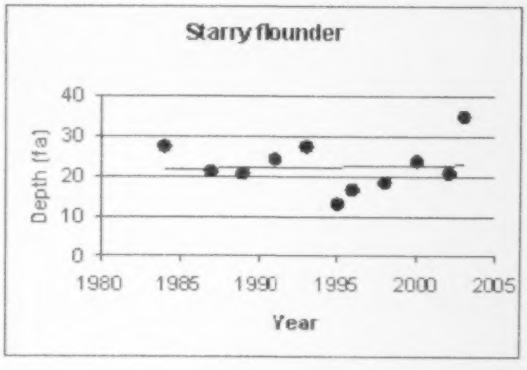


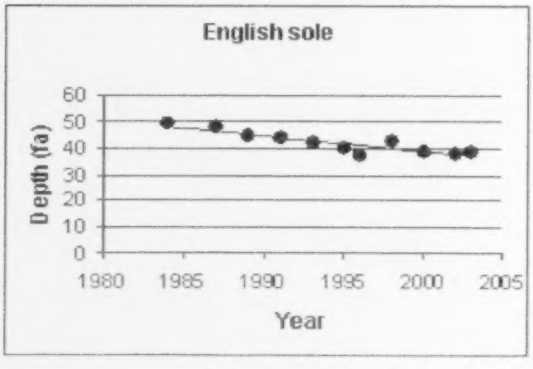
Figure 3. Mean depth over time for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003.

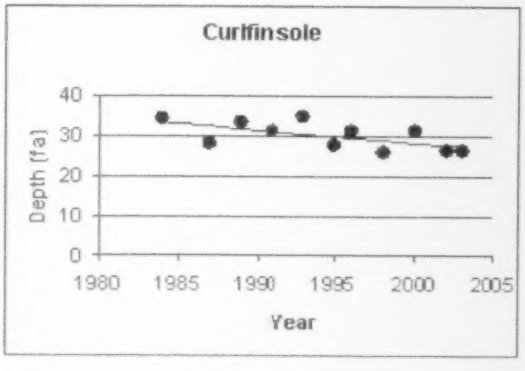












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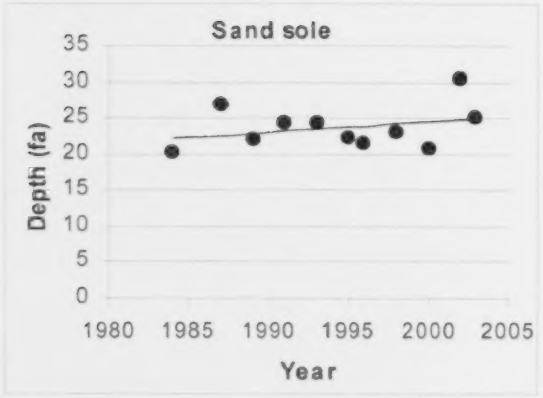

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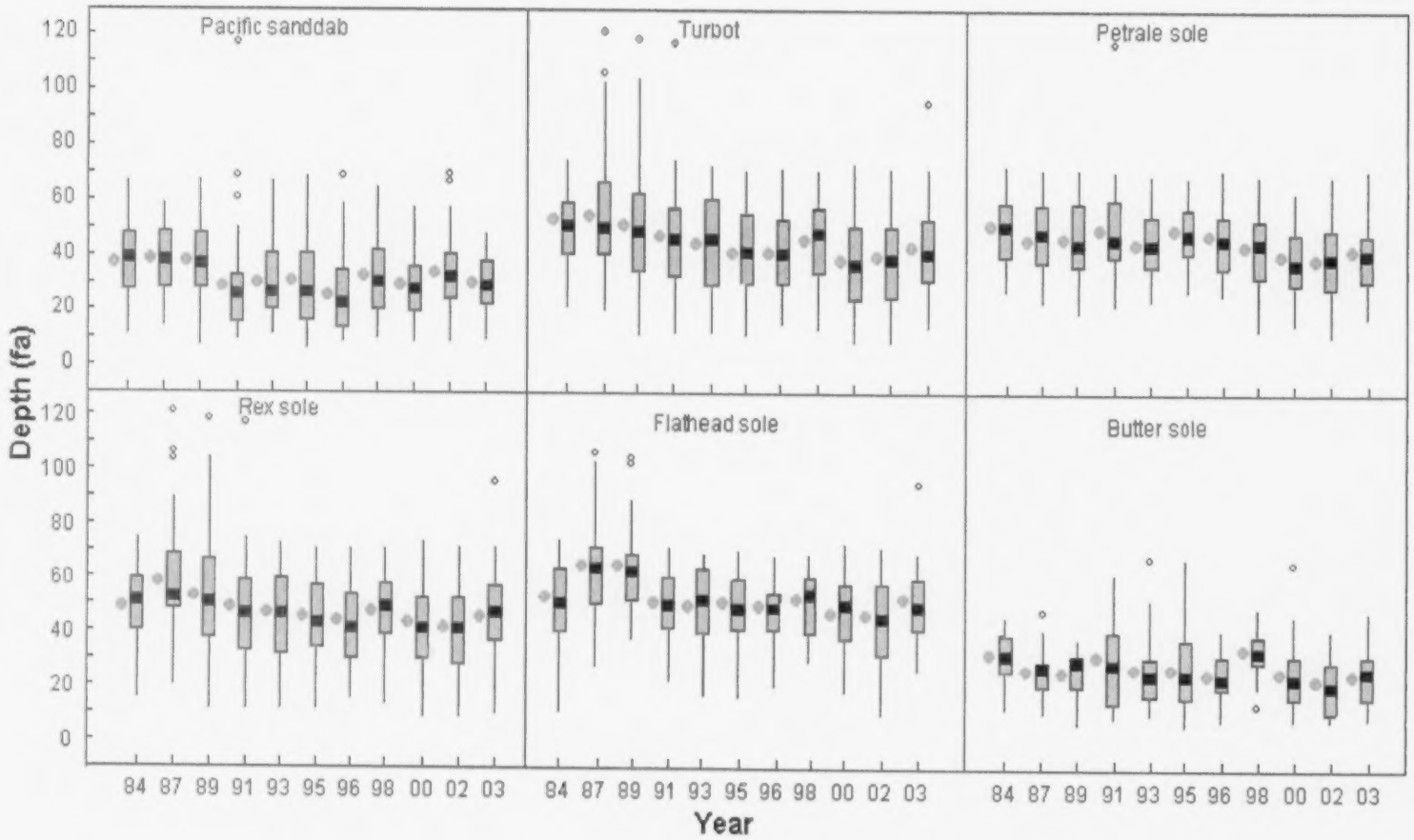
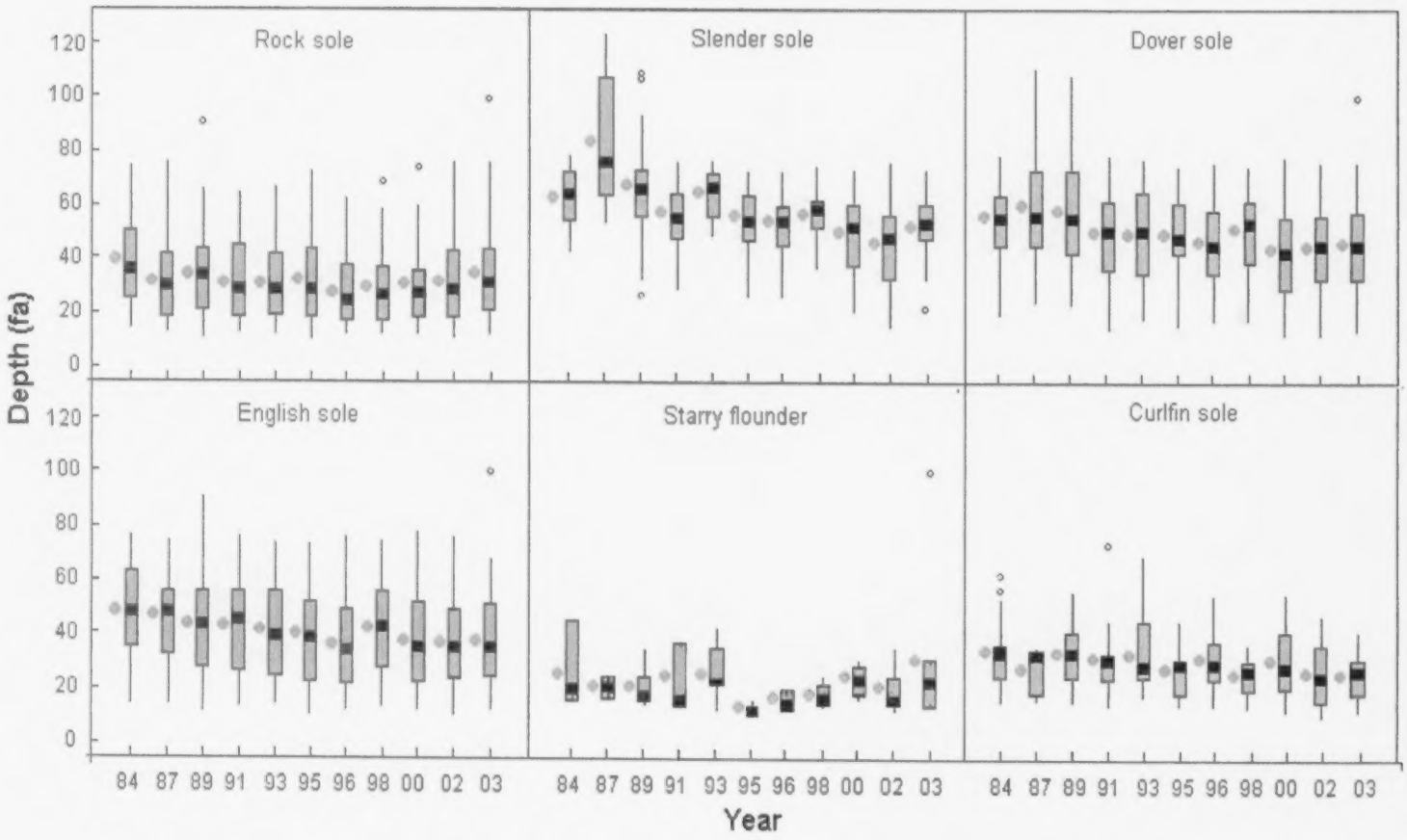


Figure 4. Boxplots of the depth distribution by year for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003. The black bar represents the median while the red dot represents the mean and the open circles are outliers.



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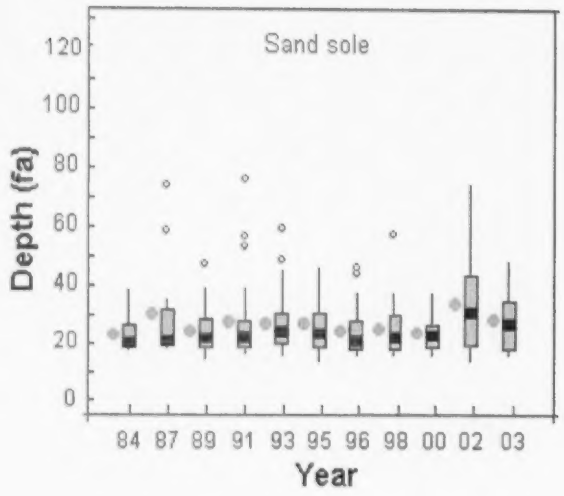

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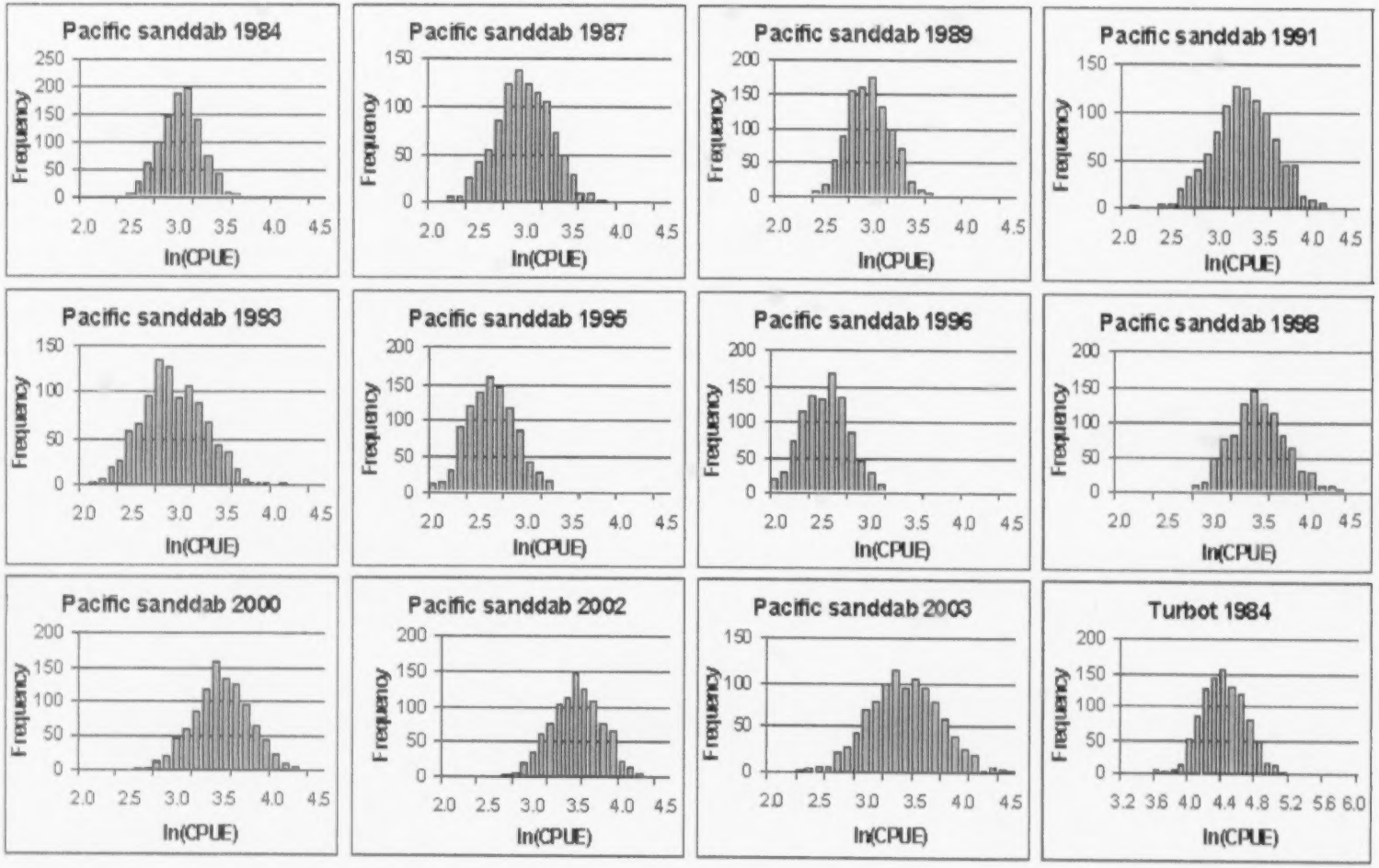
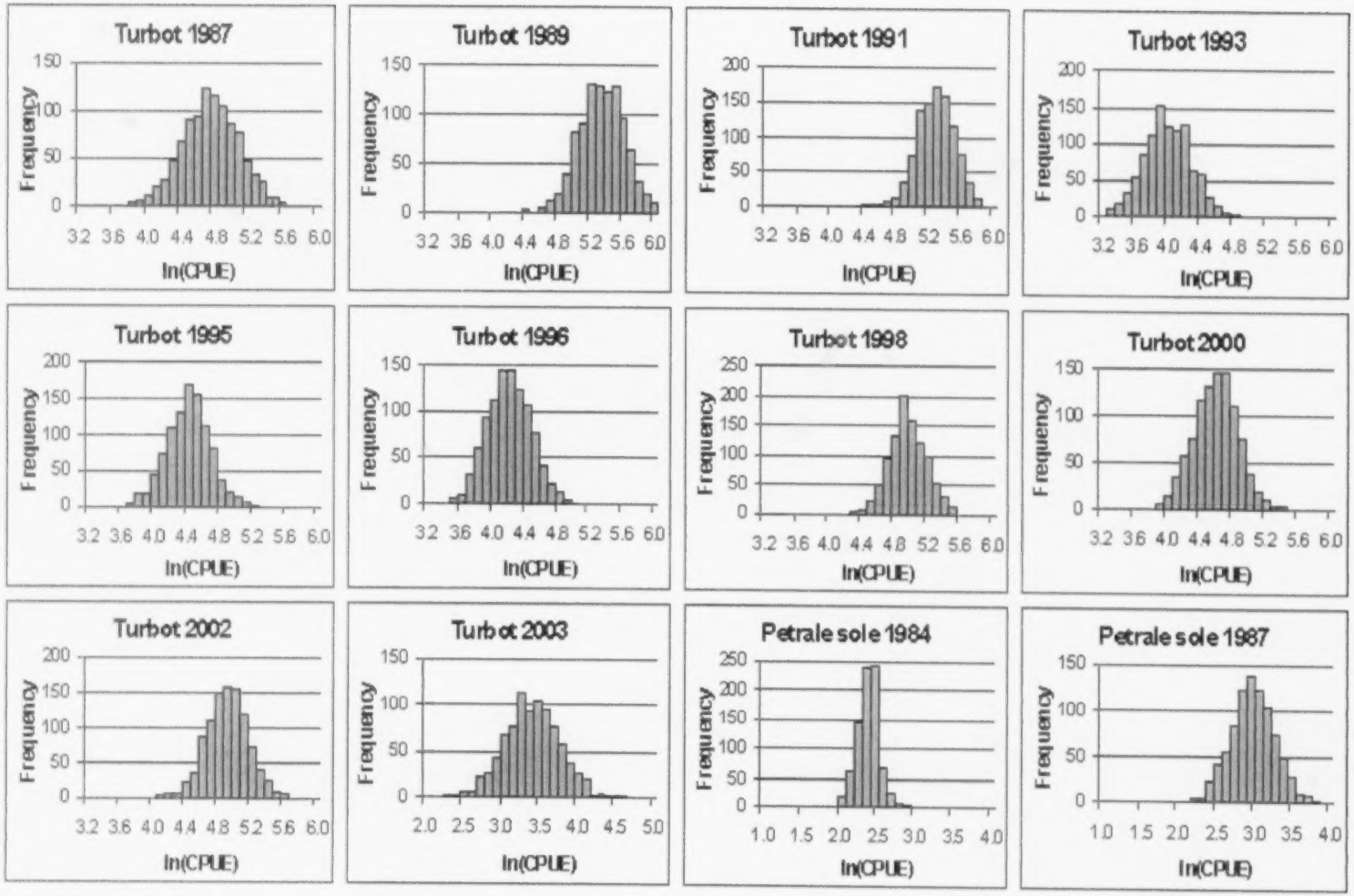


Figure 5. Distribution of bootstrapped ln(CPUE) index for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003.



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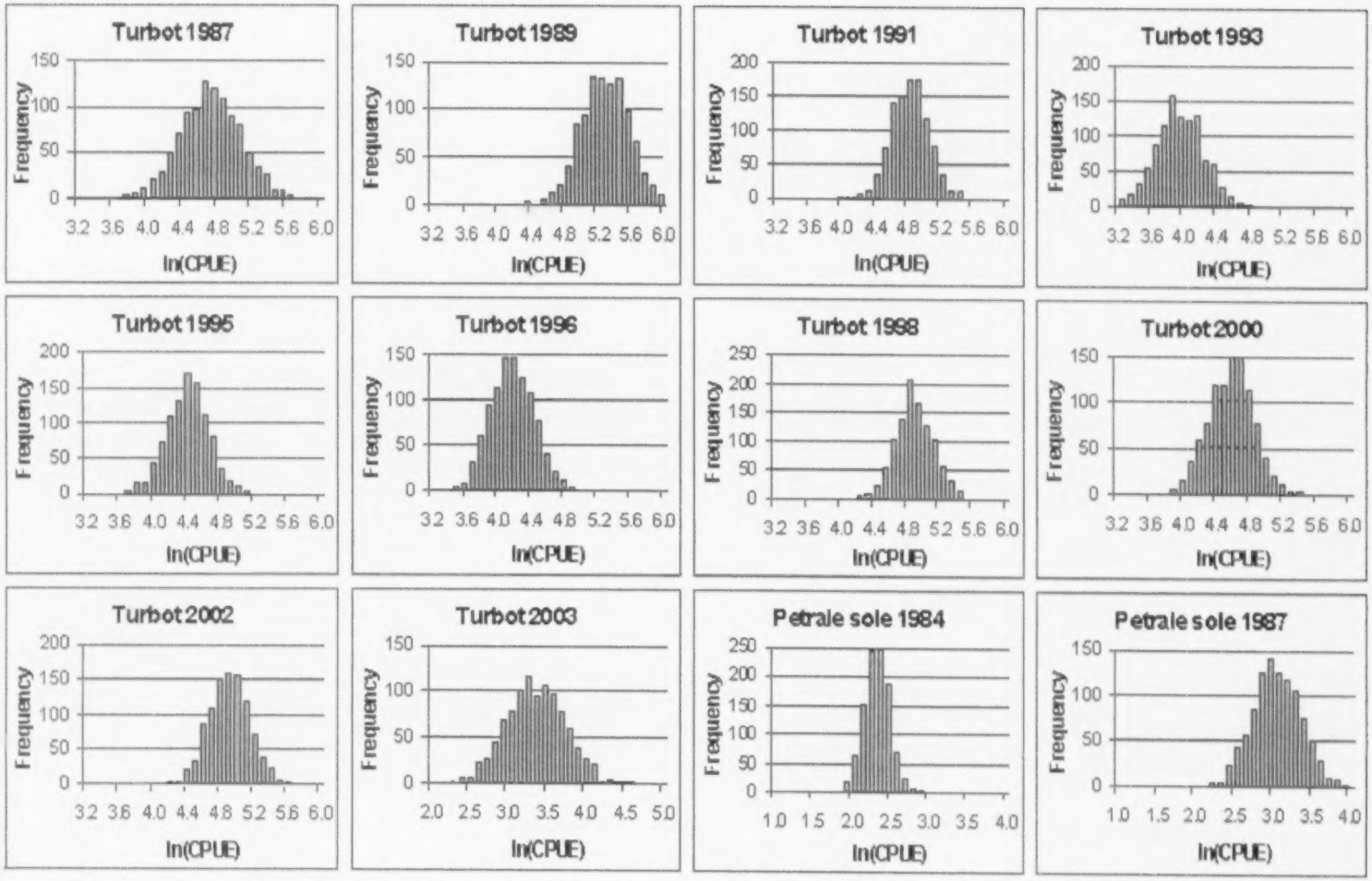

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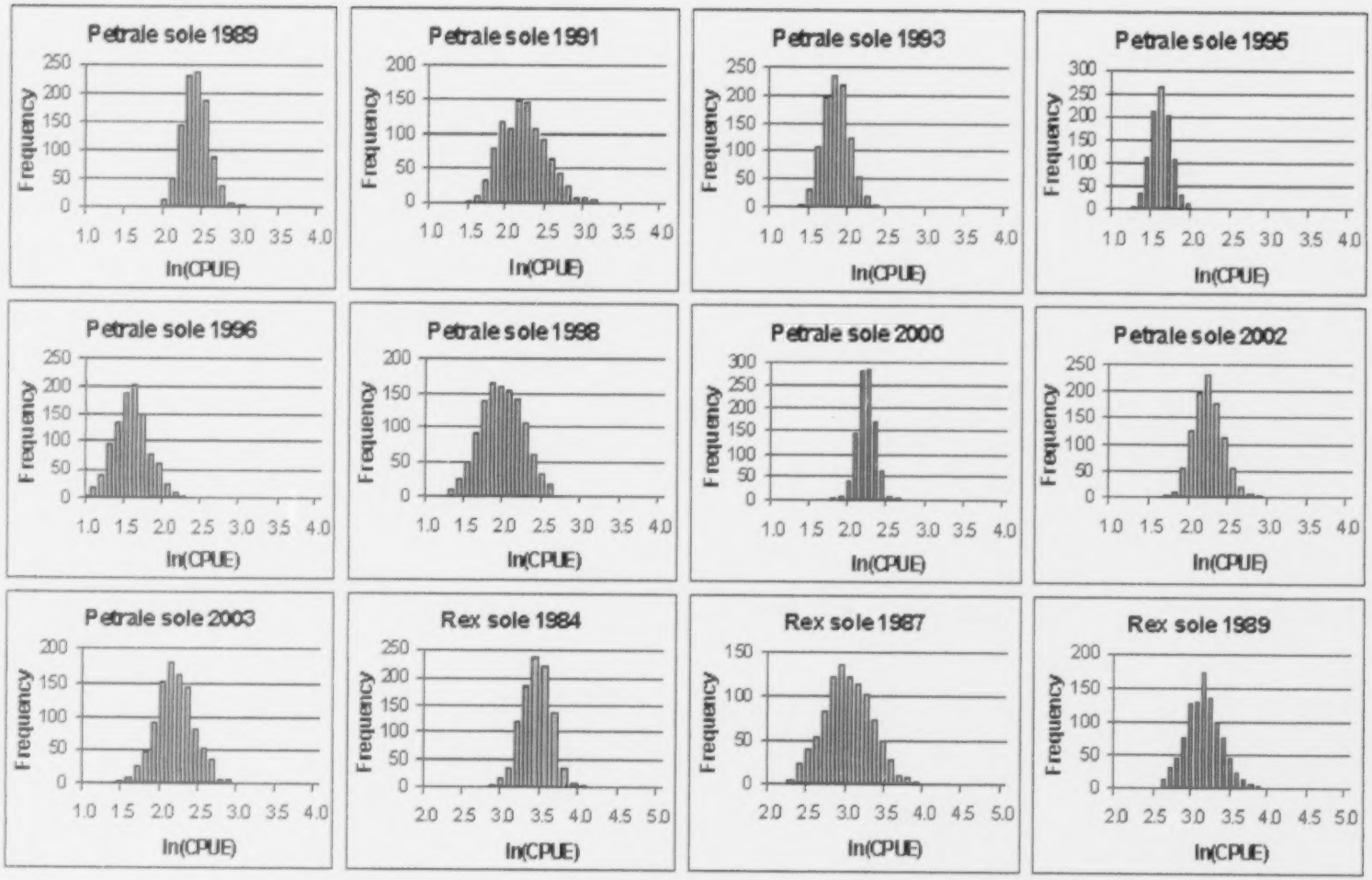

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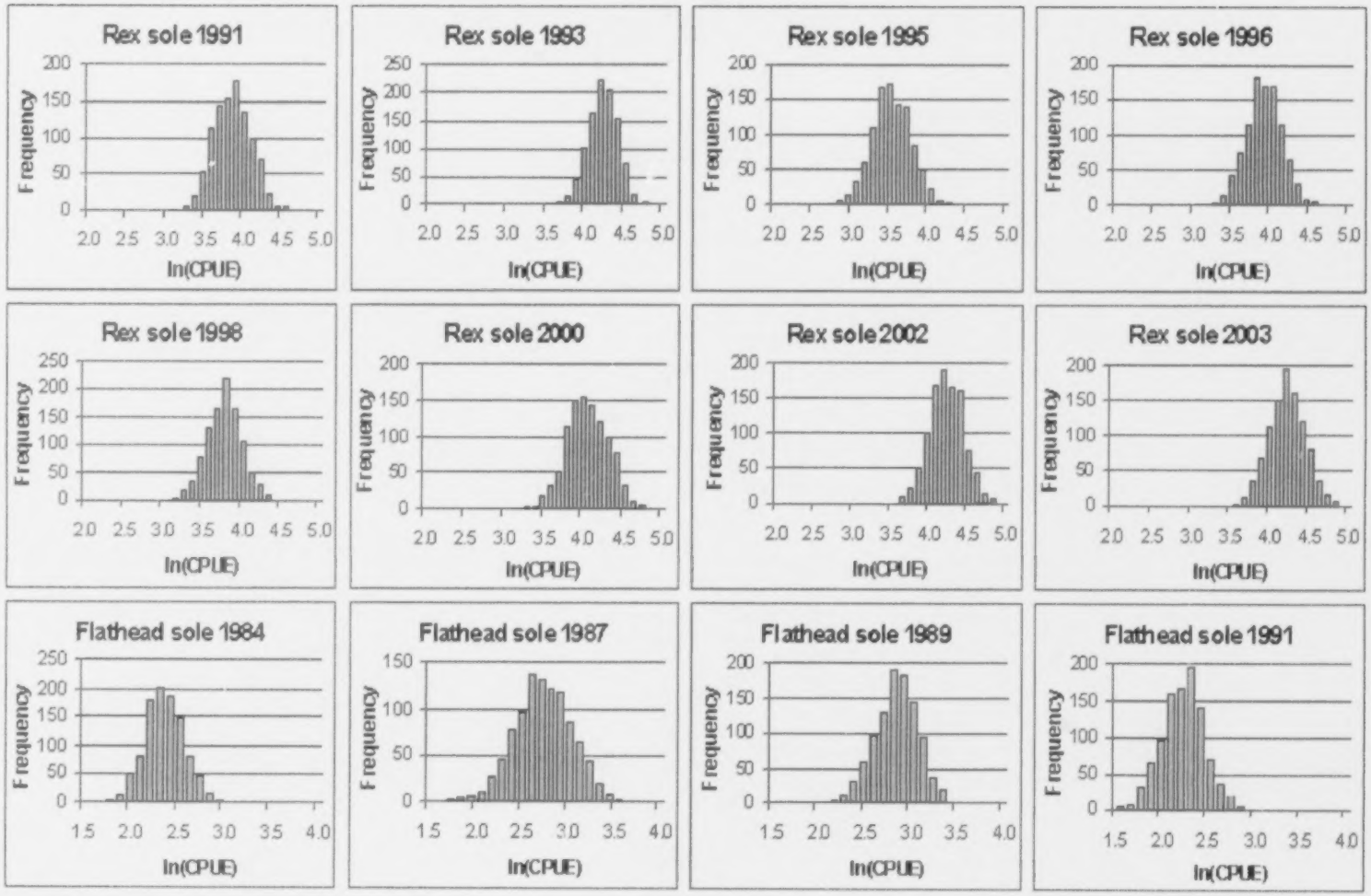

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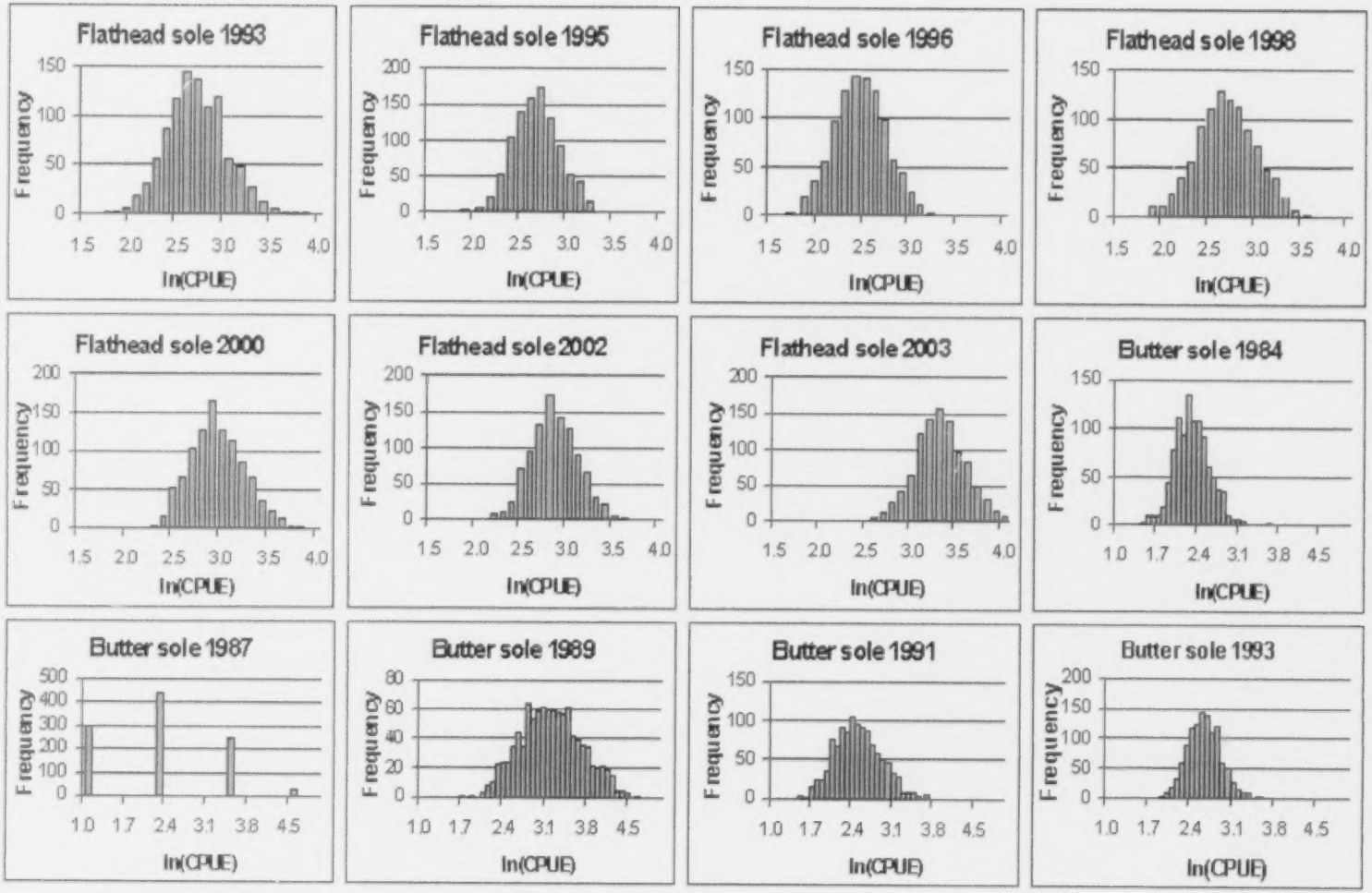

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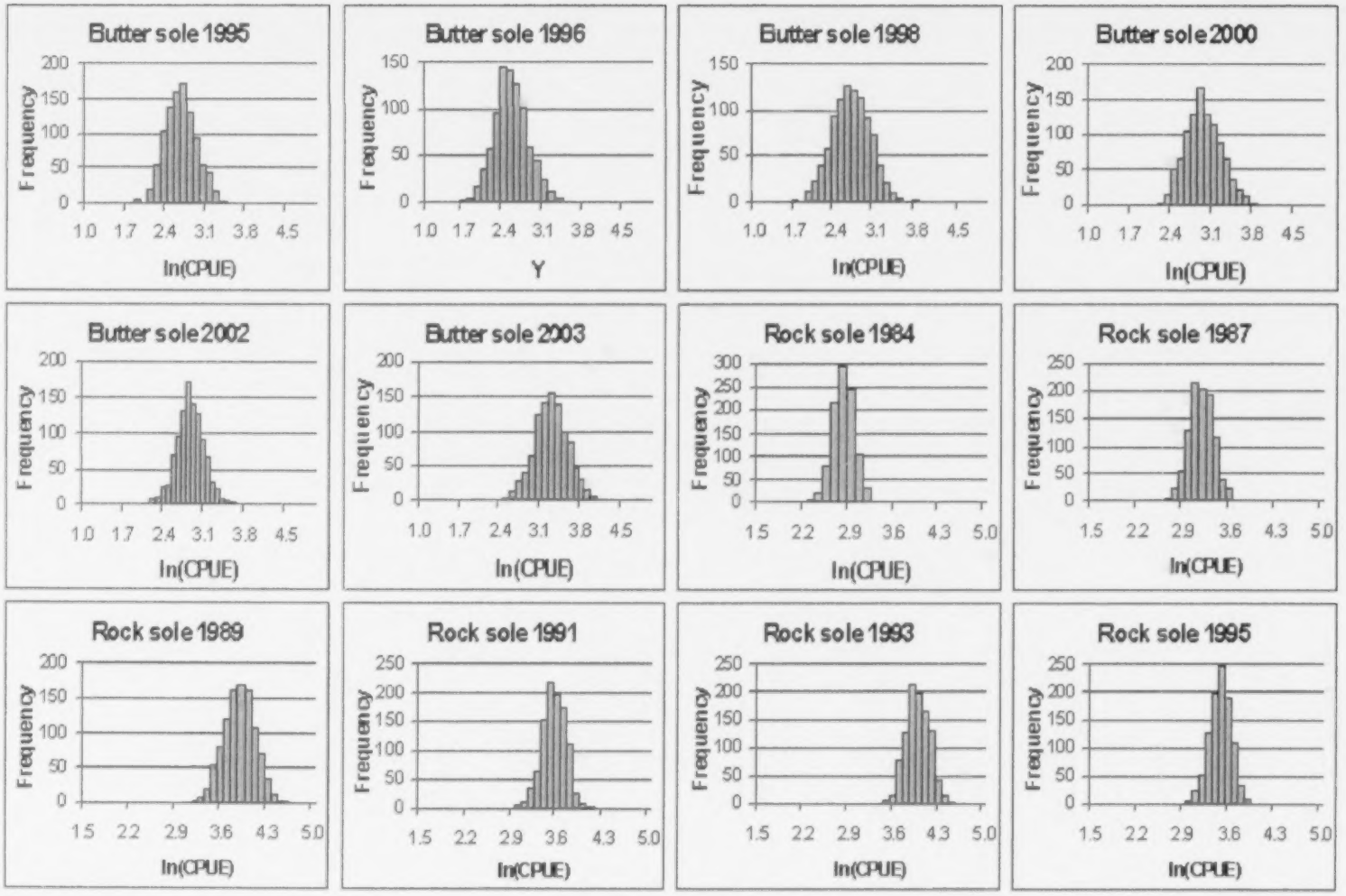

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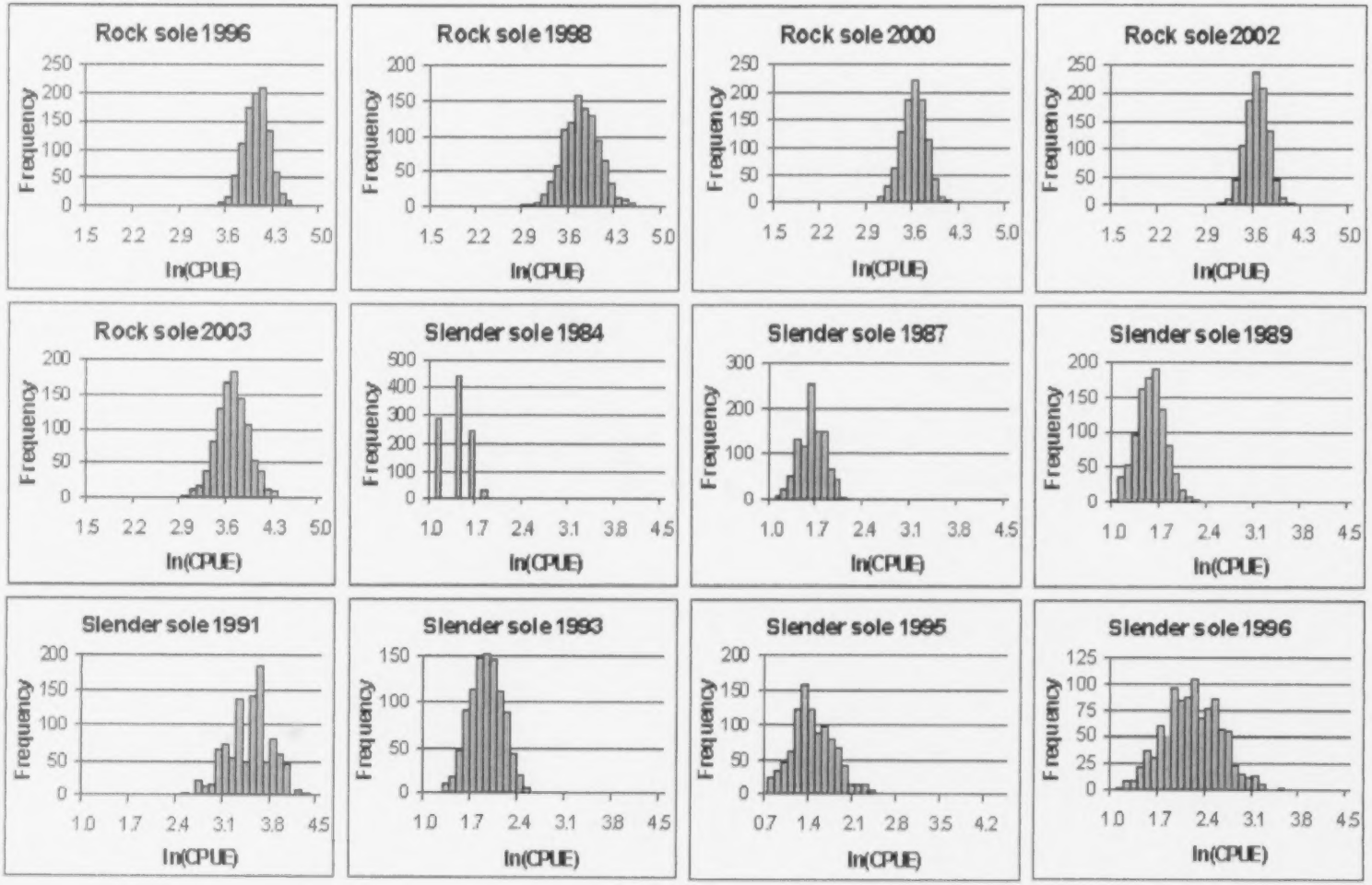

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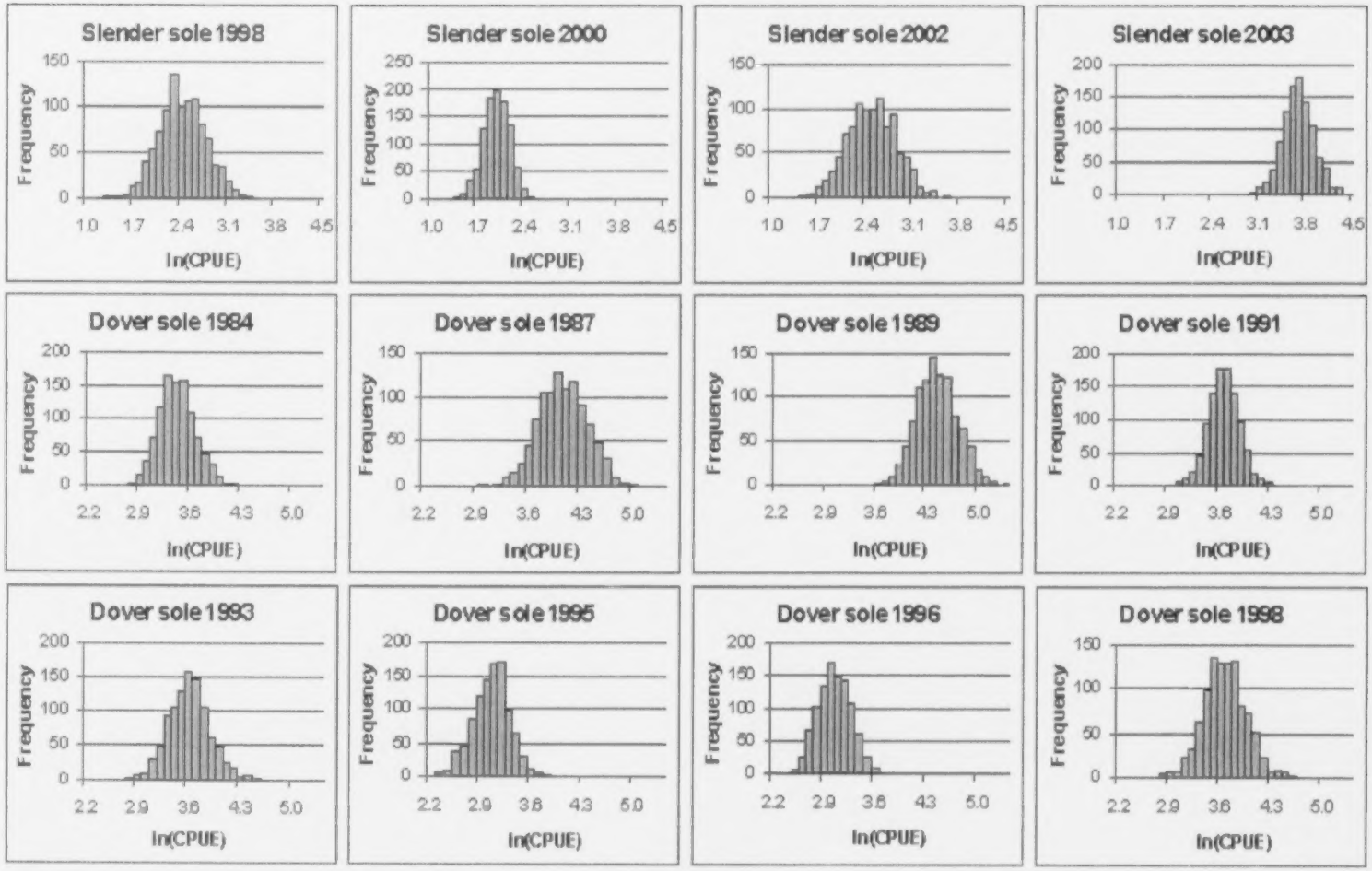

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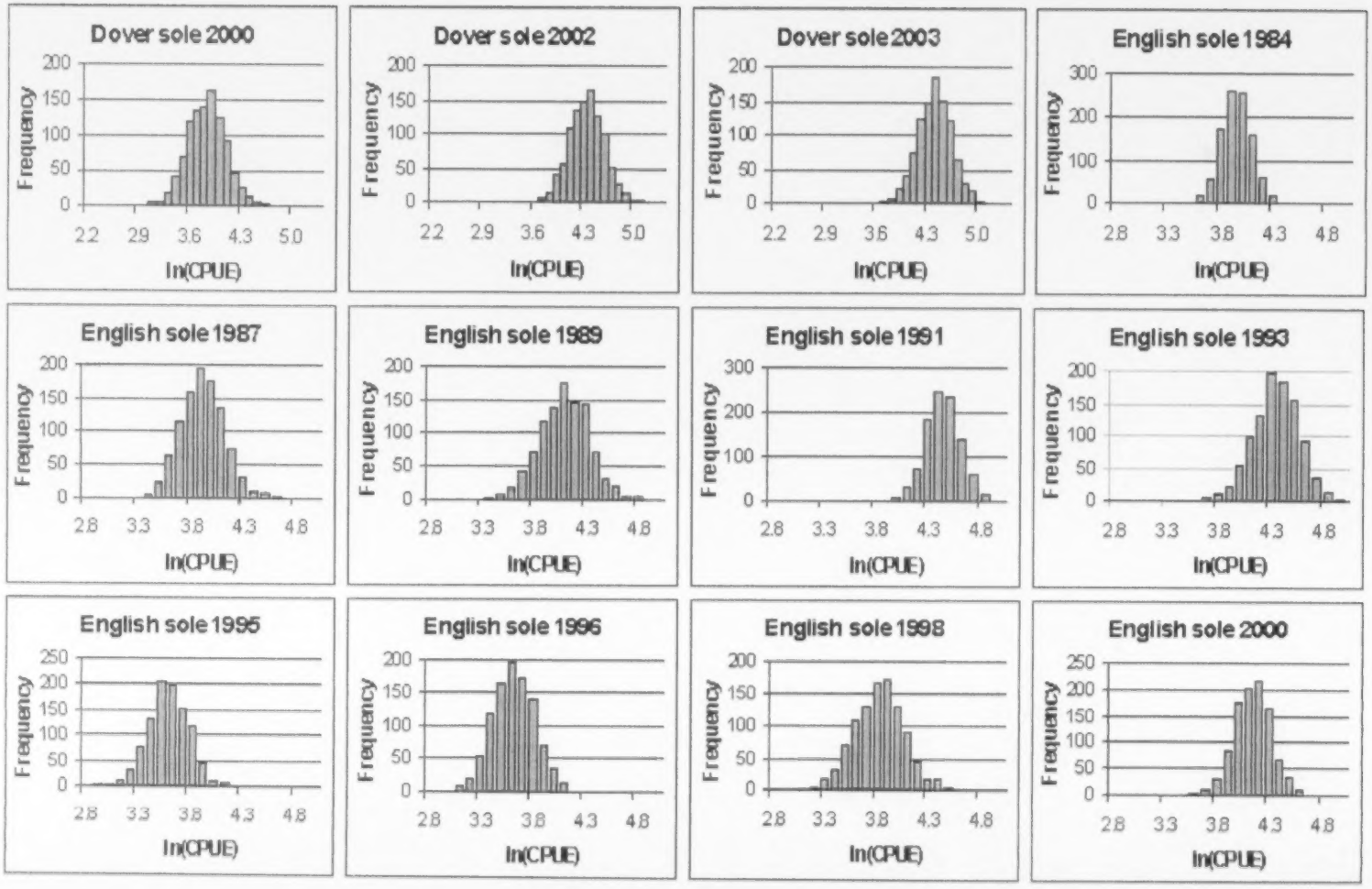

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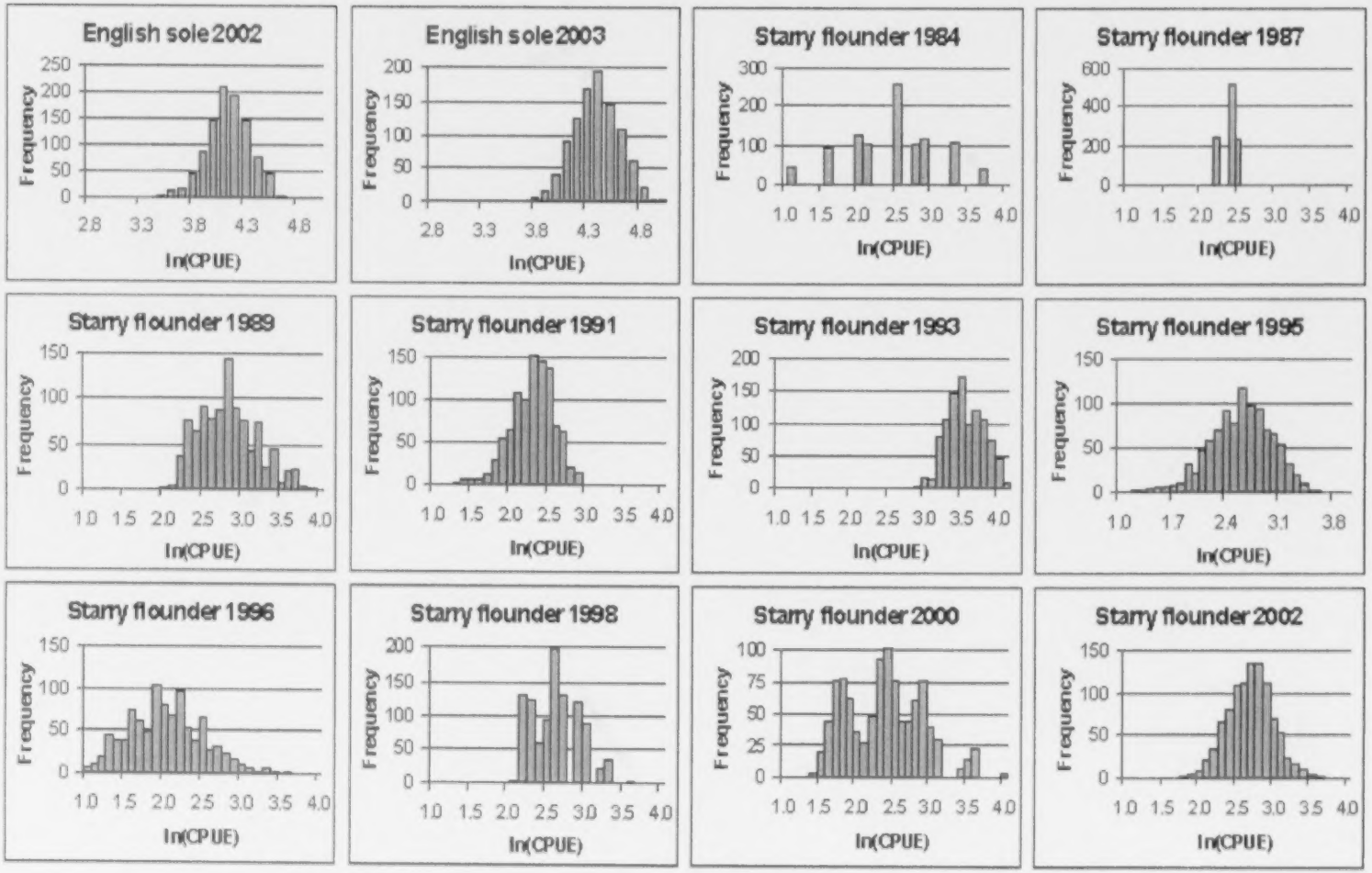

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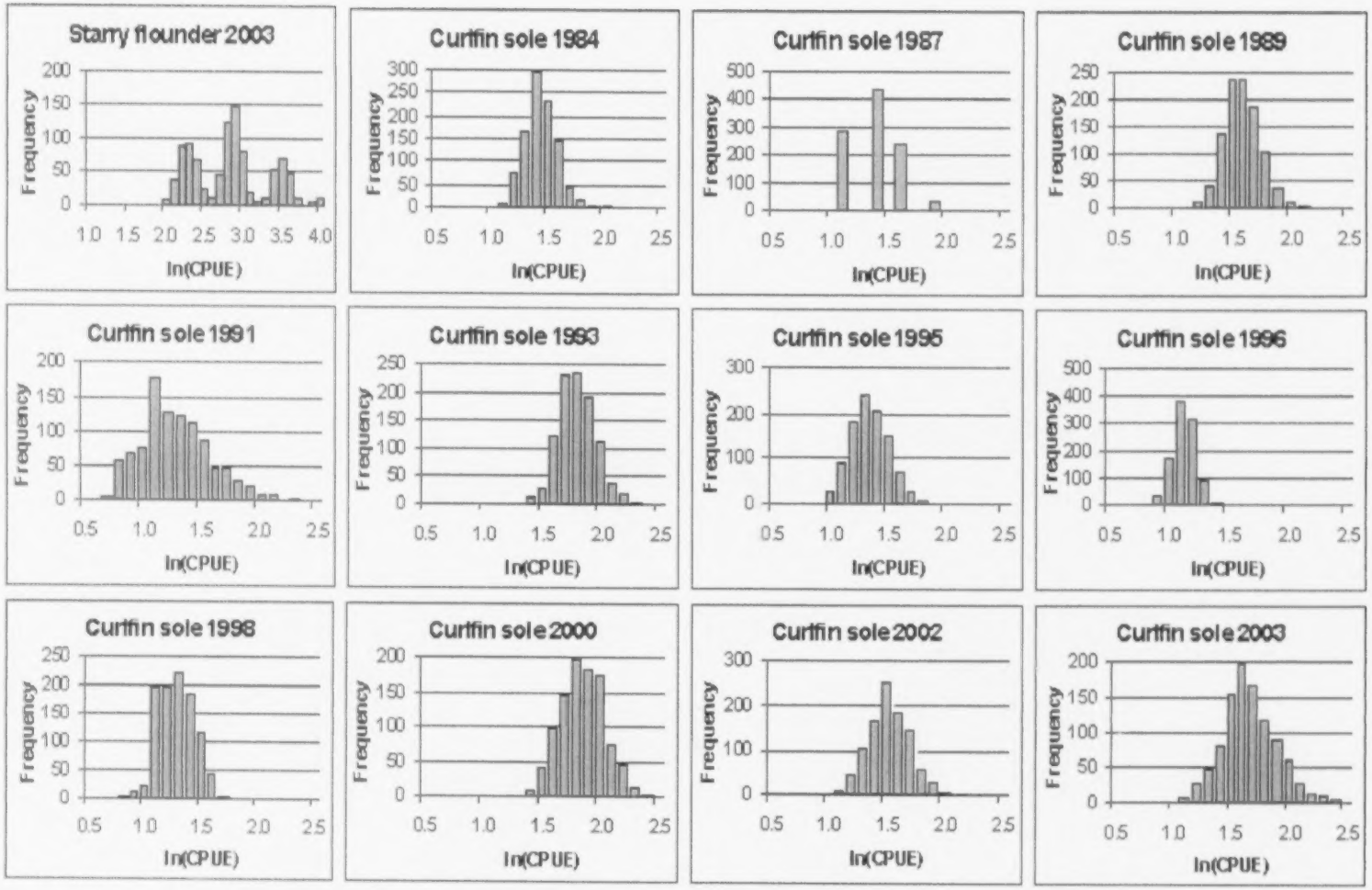

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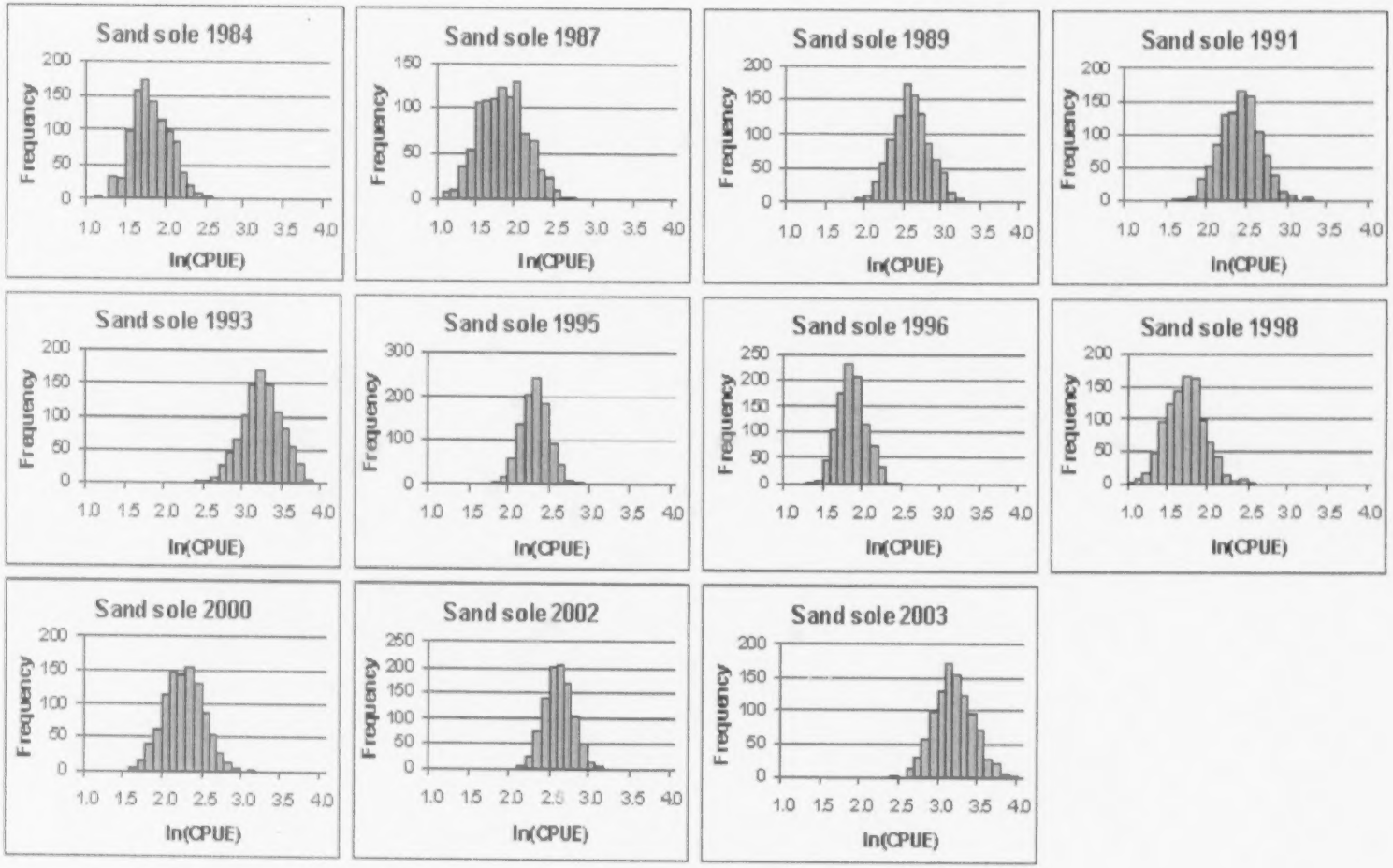

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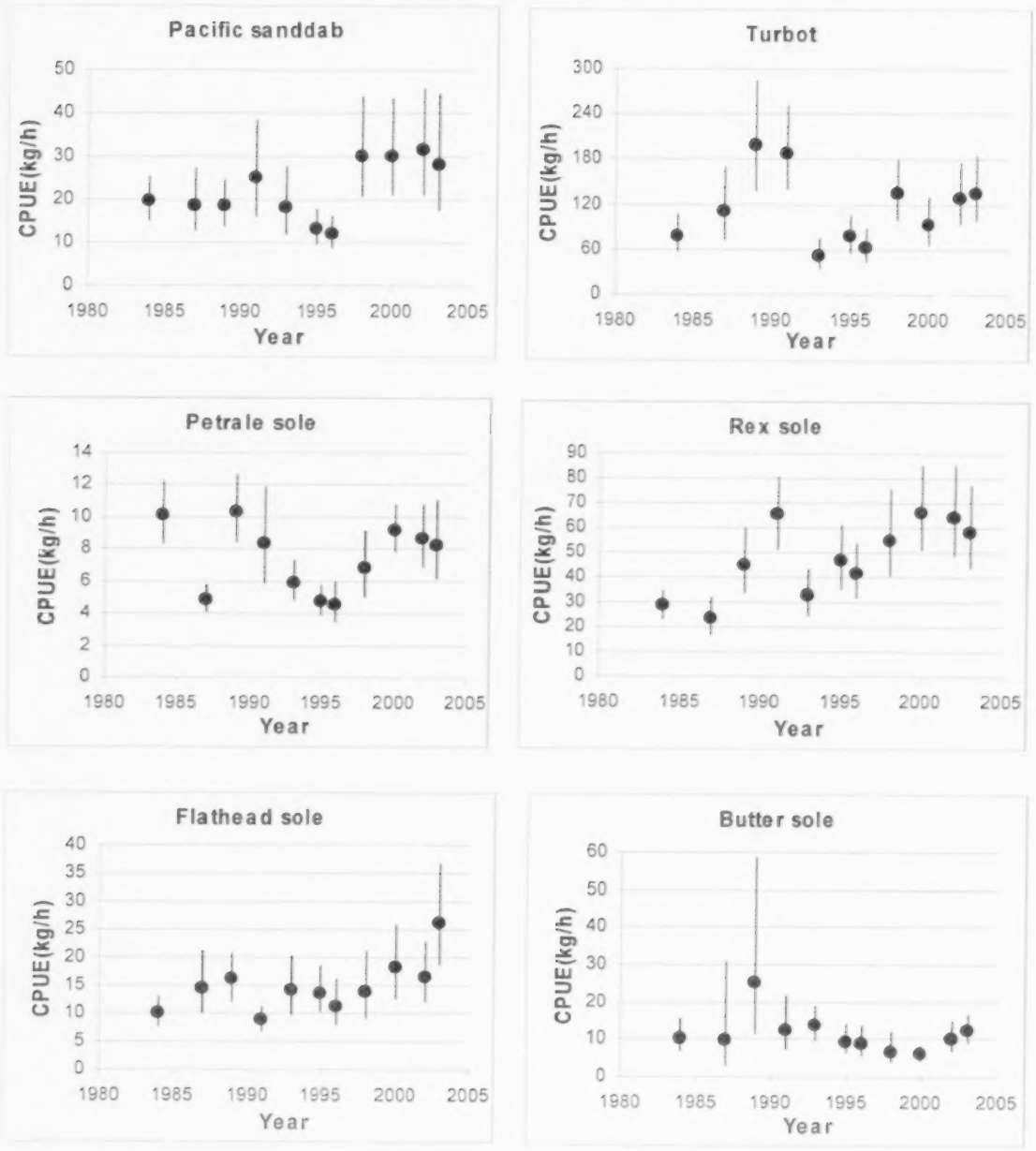
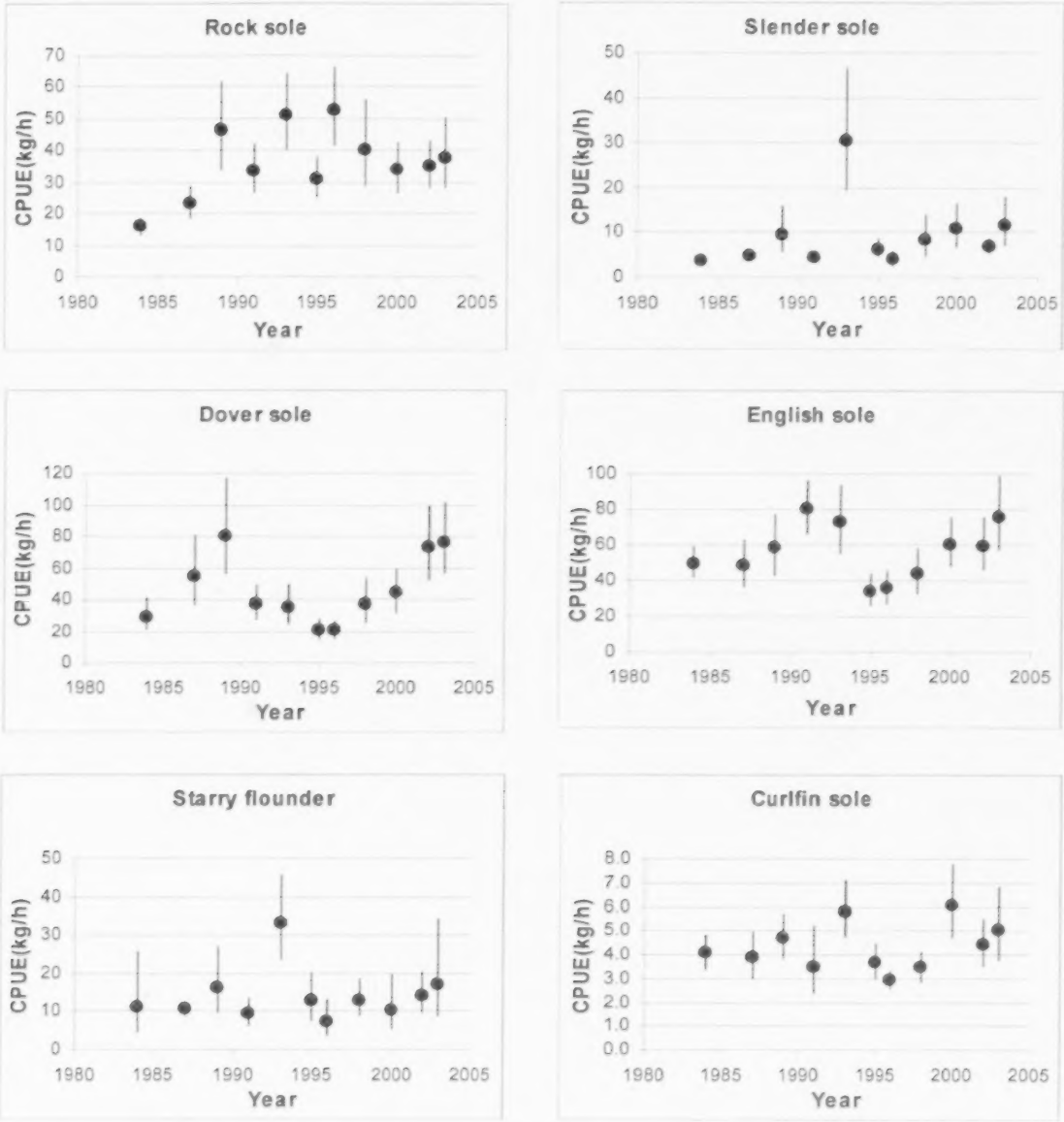


Figure 6. Back transformed mean ln(CPUE) index for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003.



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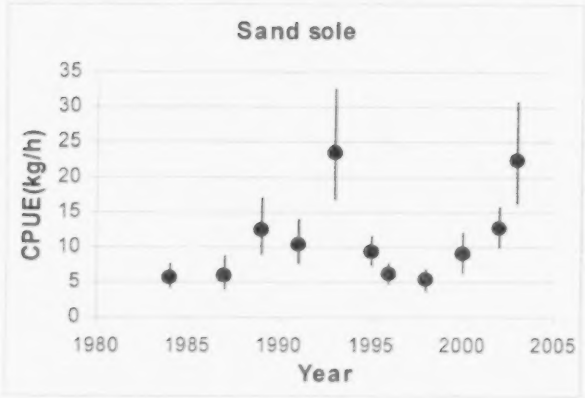

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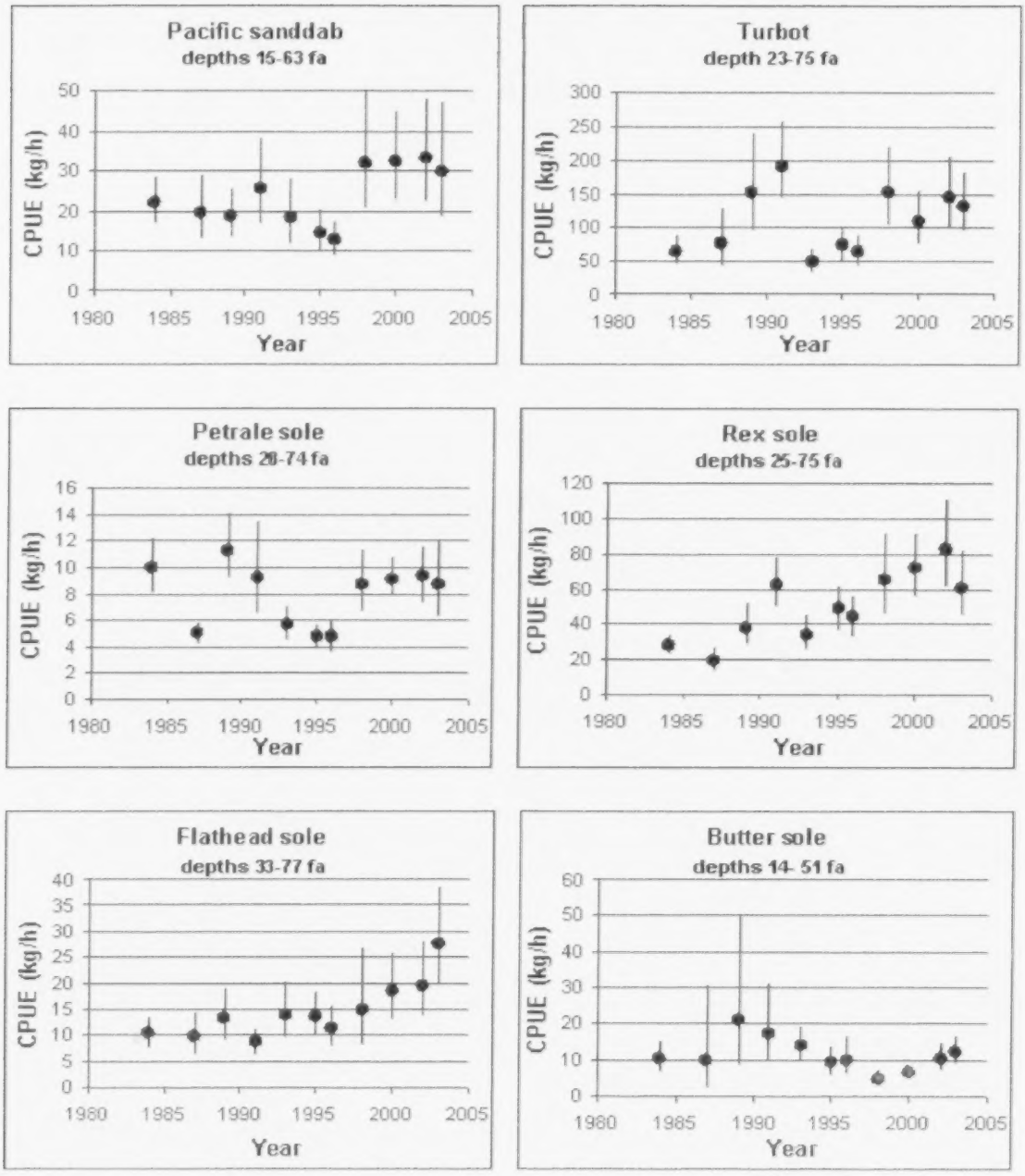
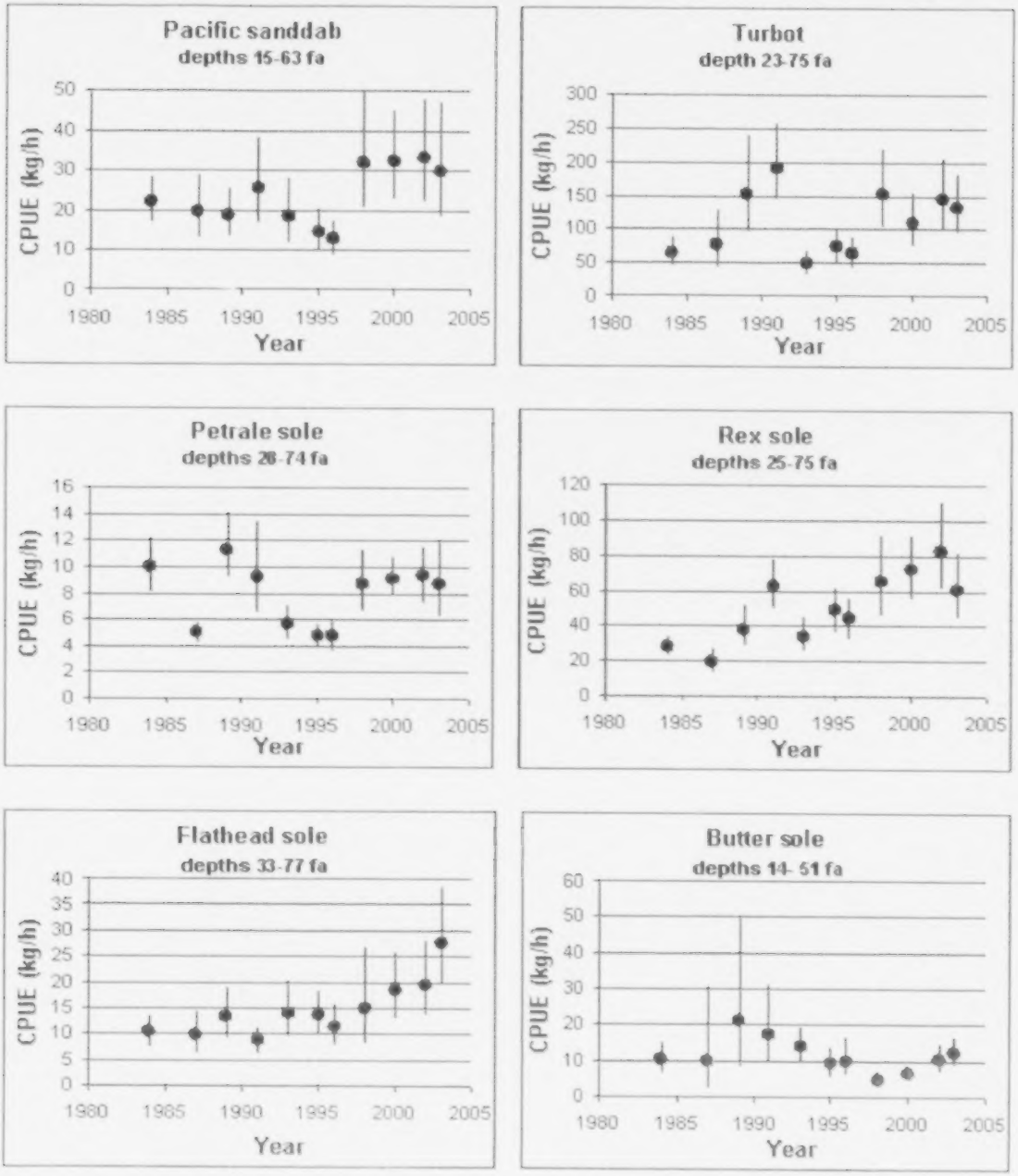


Figure 7. Backtransformed mean ln(CPUE) index for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003. The range of the depth corresponds to the 90% confidence interval for each species.



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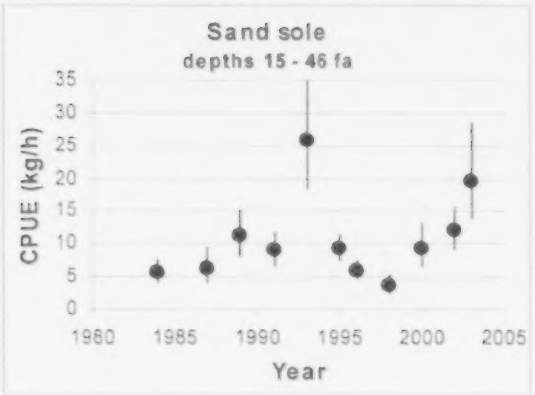

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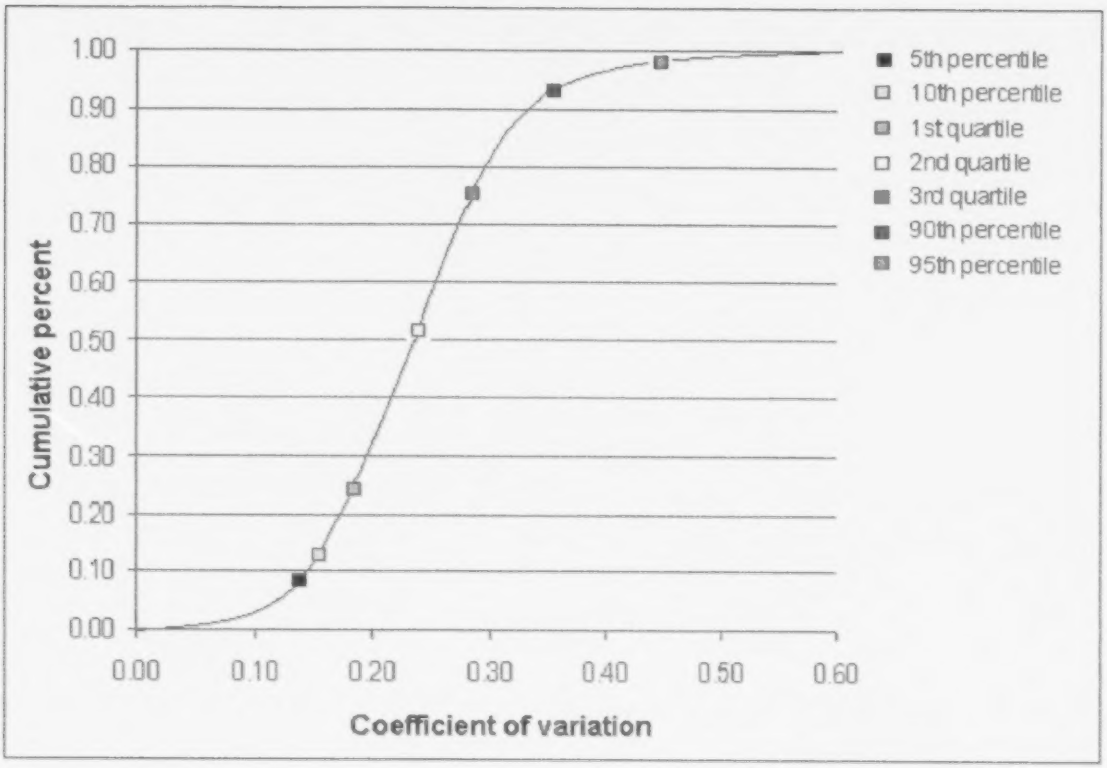


Figure 8. Cumulative percent frequency for the coefficient of variation for the distributions of backtransformed ln(CPUE) for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003 (years and species combined).

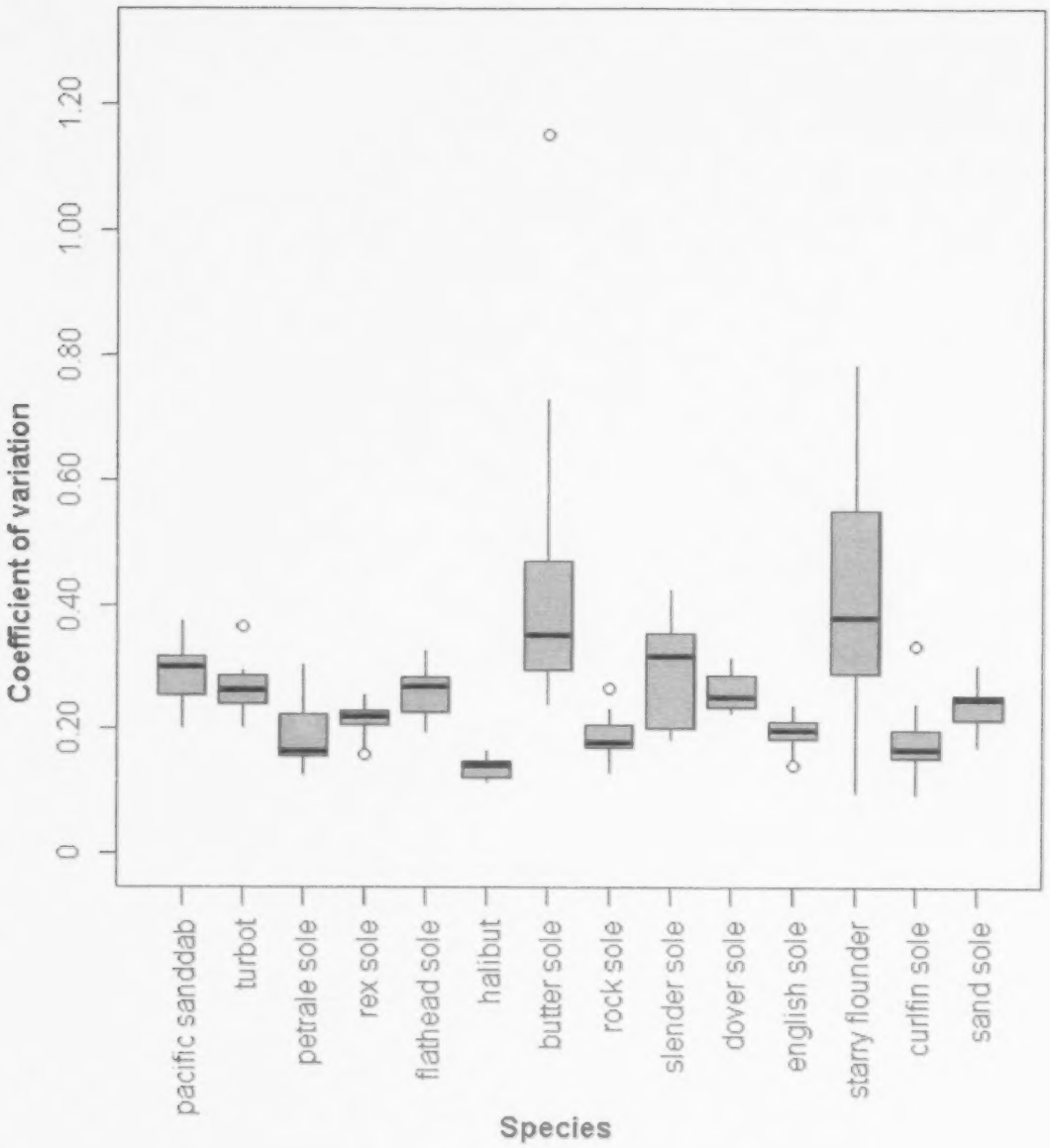


Figure 9. Boxplots of the coefficient of variation for the distributions of backtransformed ln(CPUE) for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003.

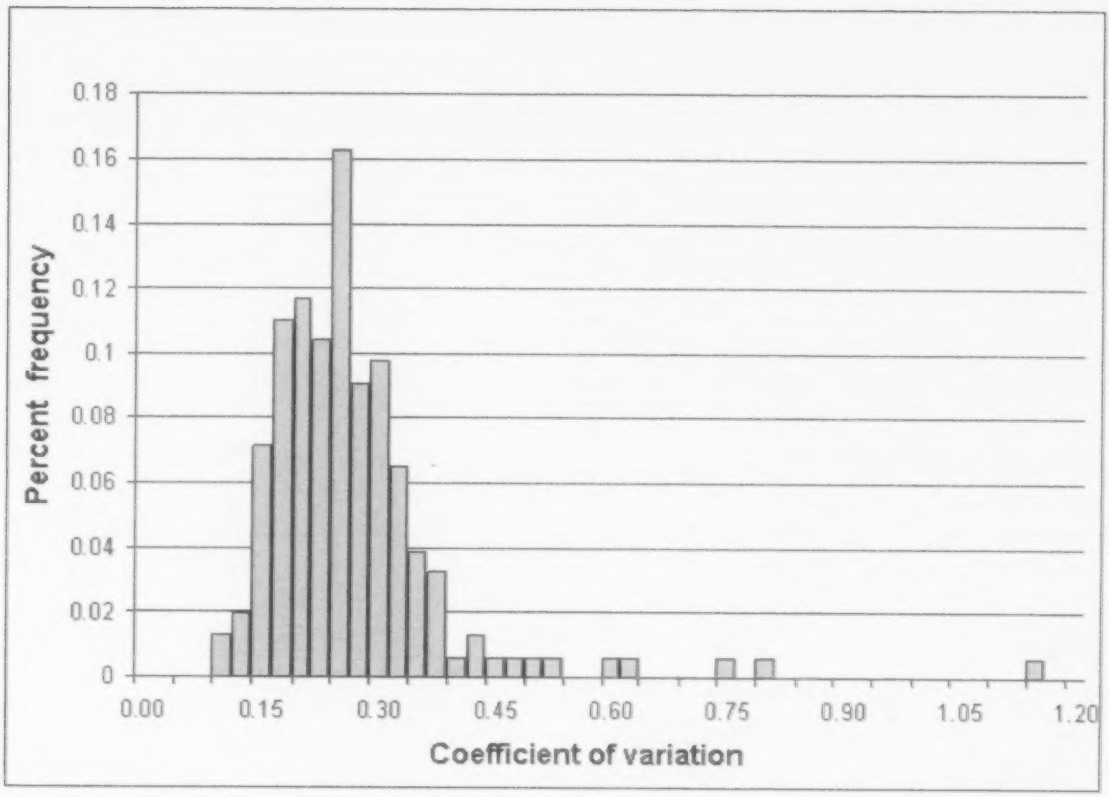


Figure 10. Percent frequency distribution for the coefficient of variation for the distributions of backtransformed ln(CPUE) for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003 (years and species combined).

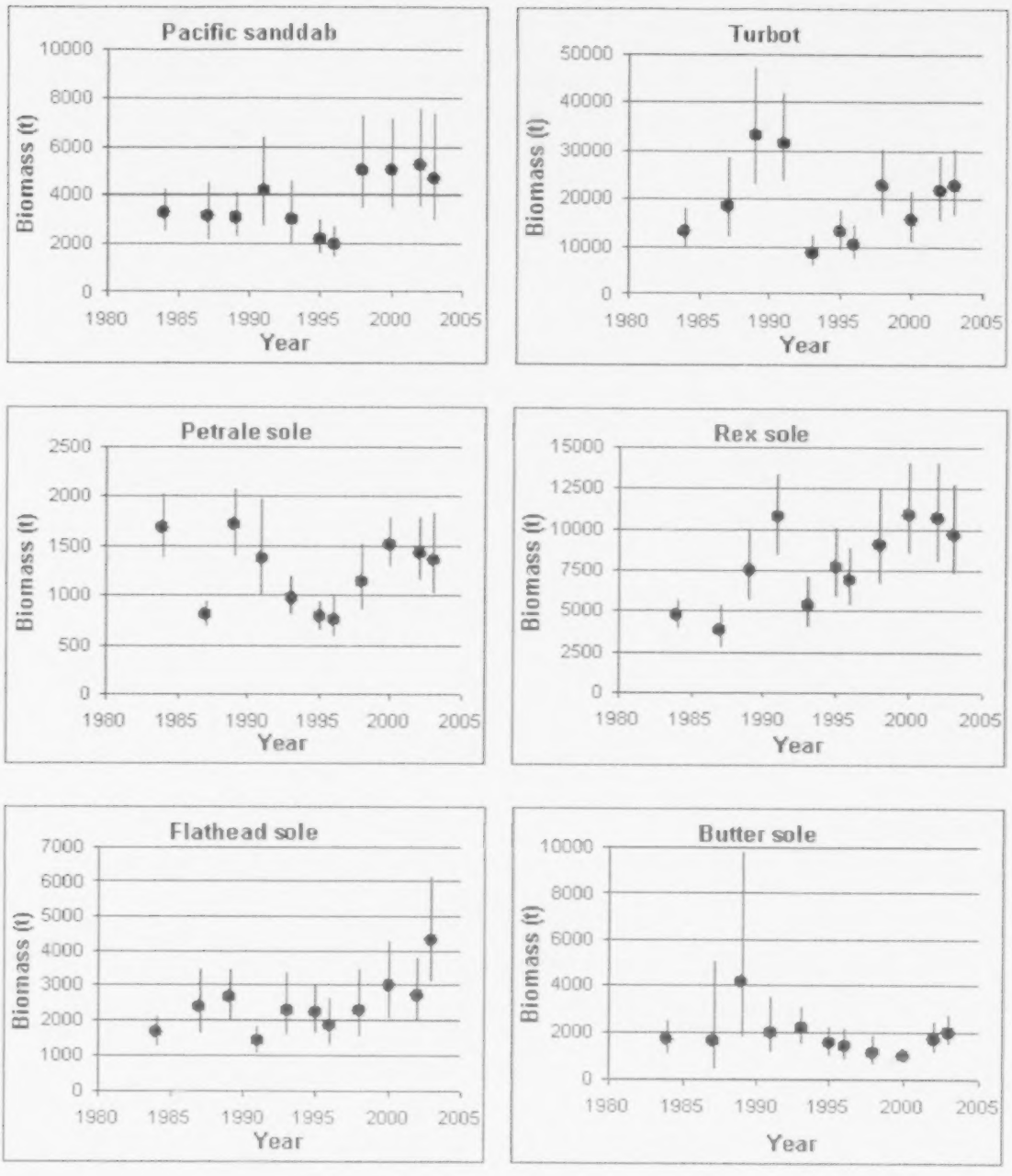
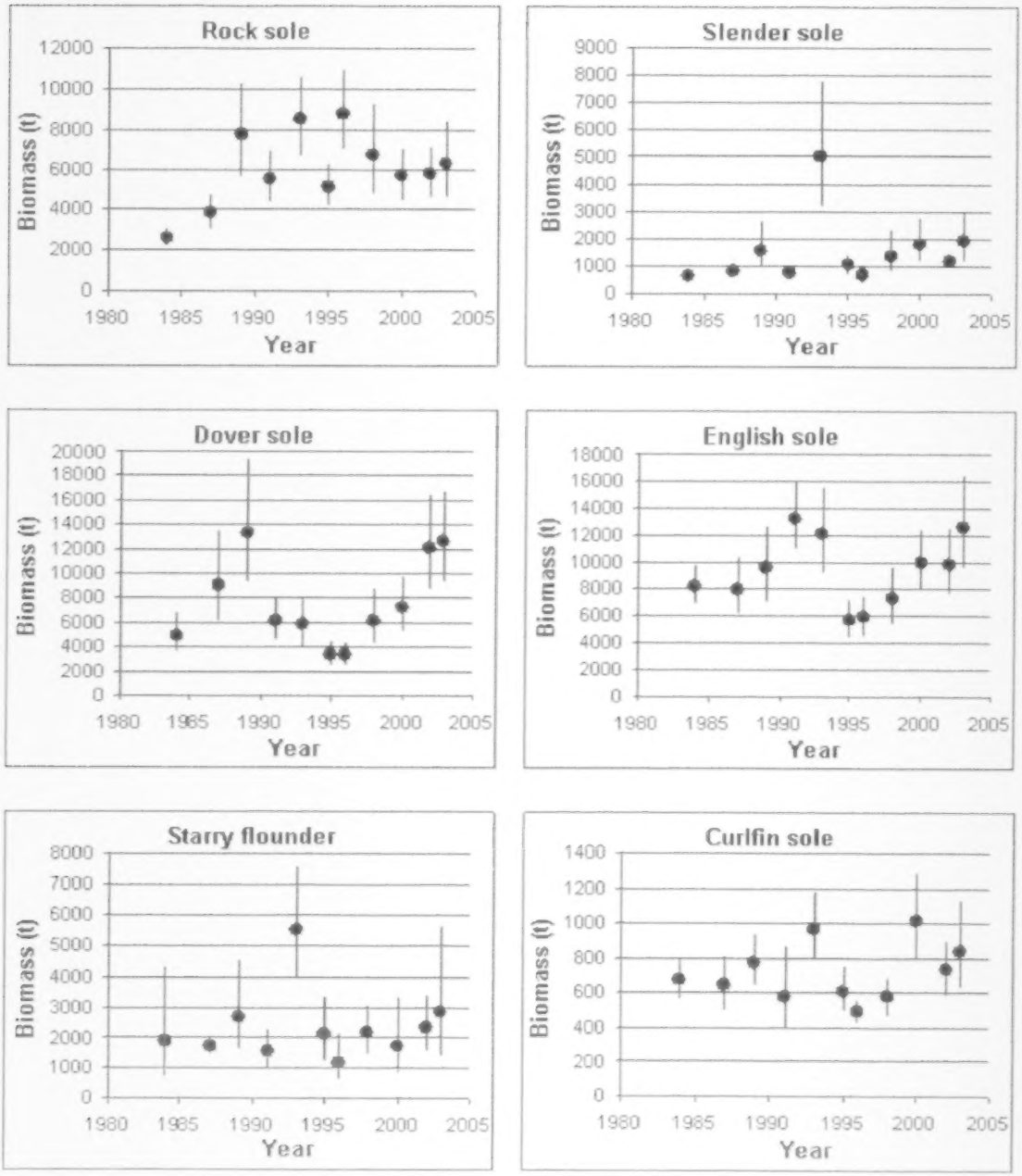


Figure 11. Biomass estimates and 90% confidence interval (all depths) determined from the backtransformed mean ln(CPUE) index for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys conducted from 1984-2003.



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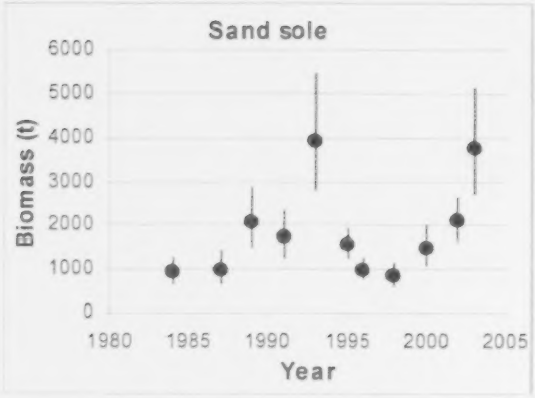


Figure 11. cont'd

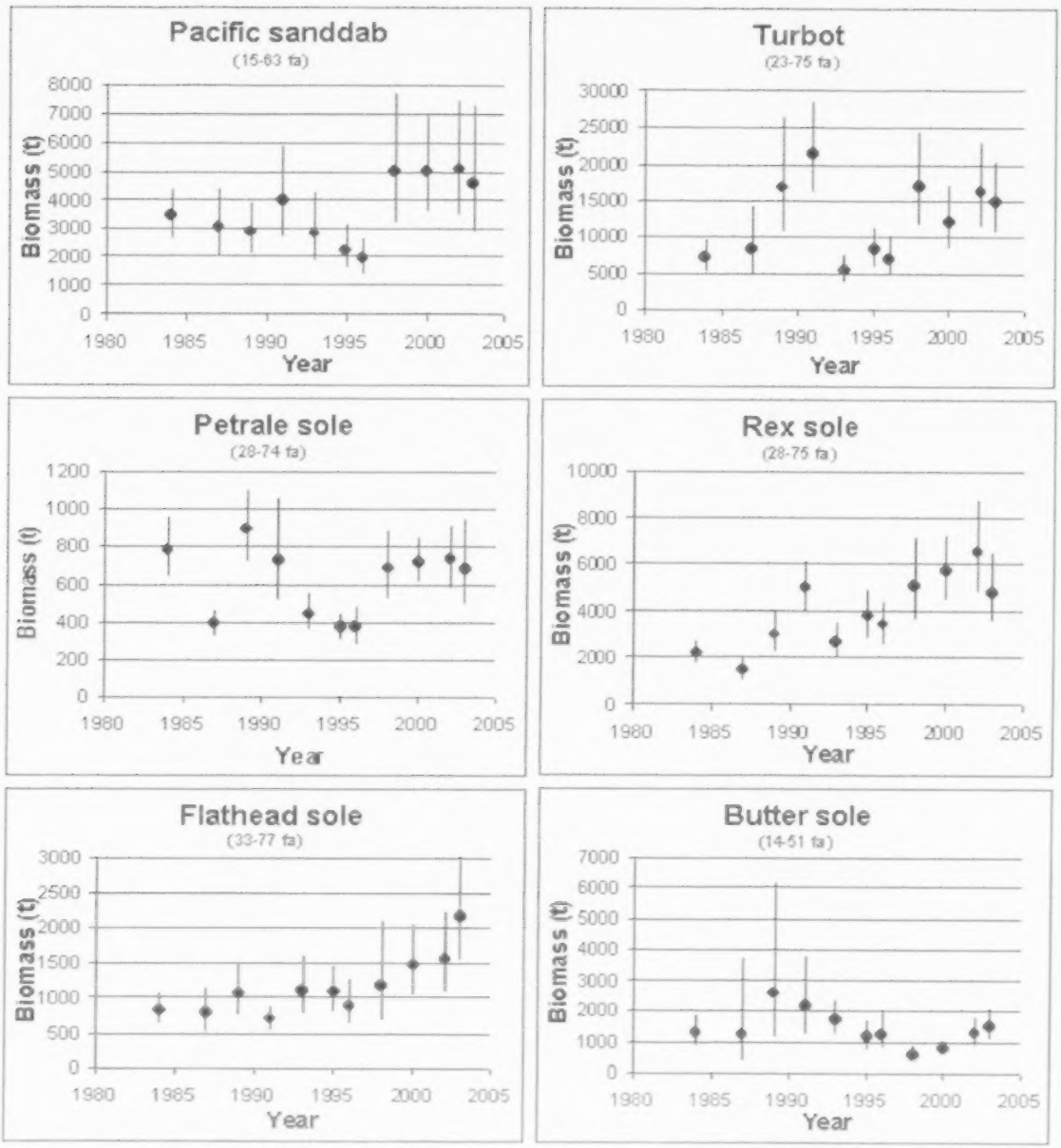
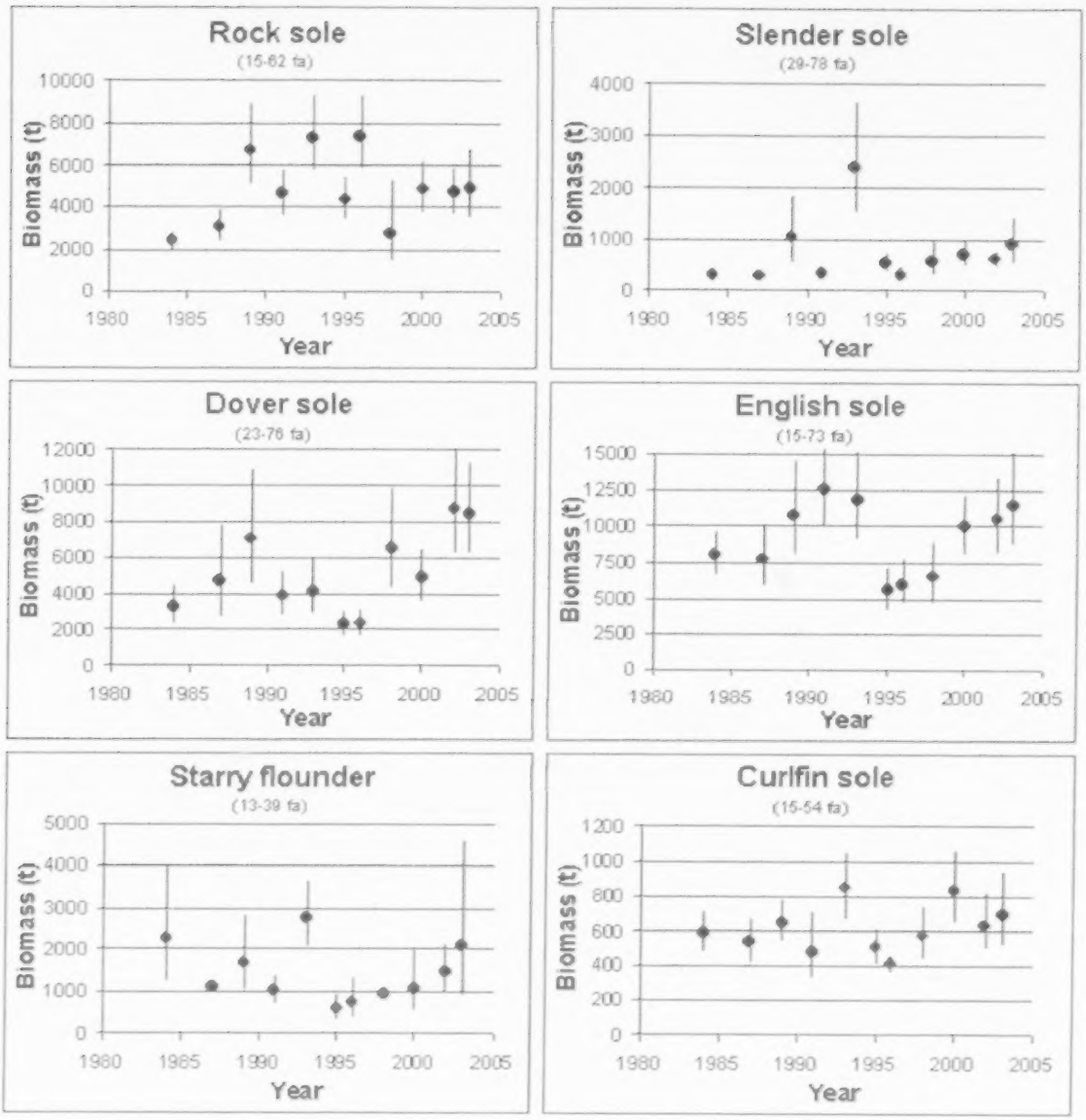


Figure 12. Biomass estimates and 90% confidence interval for data from the 90% confidence interval of the species depth distribution, determined from the back transformed mean ln(CPUE) for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003.



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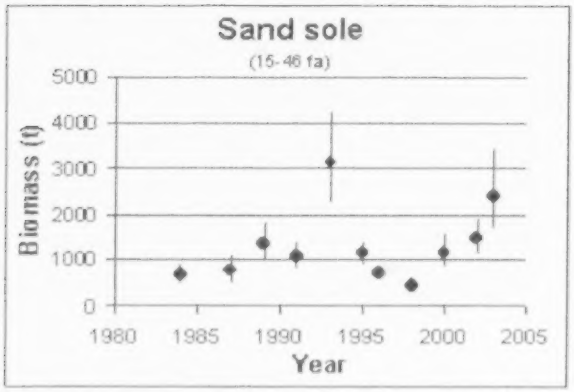

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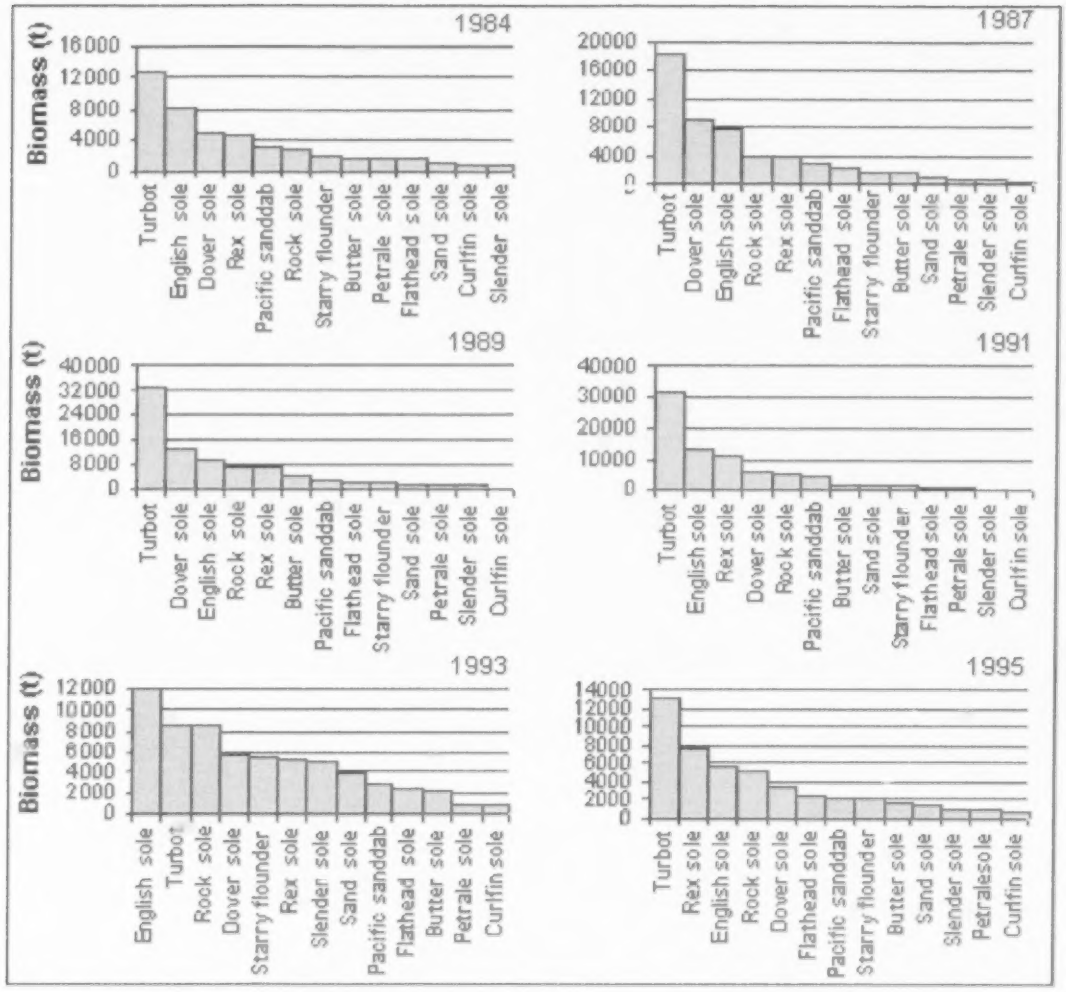

Figure 13. Summaries of annual biomass for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003 determined from CPUE.

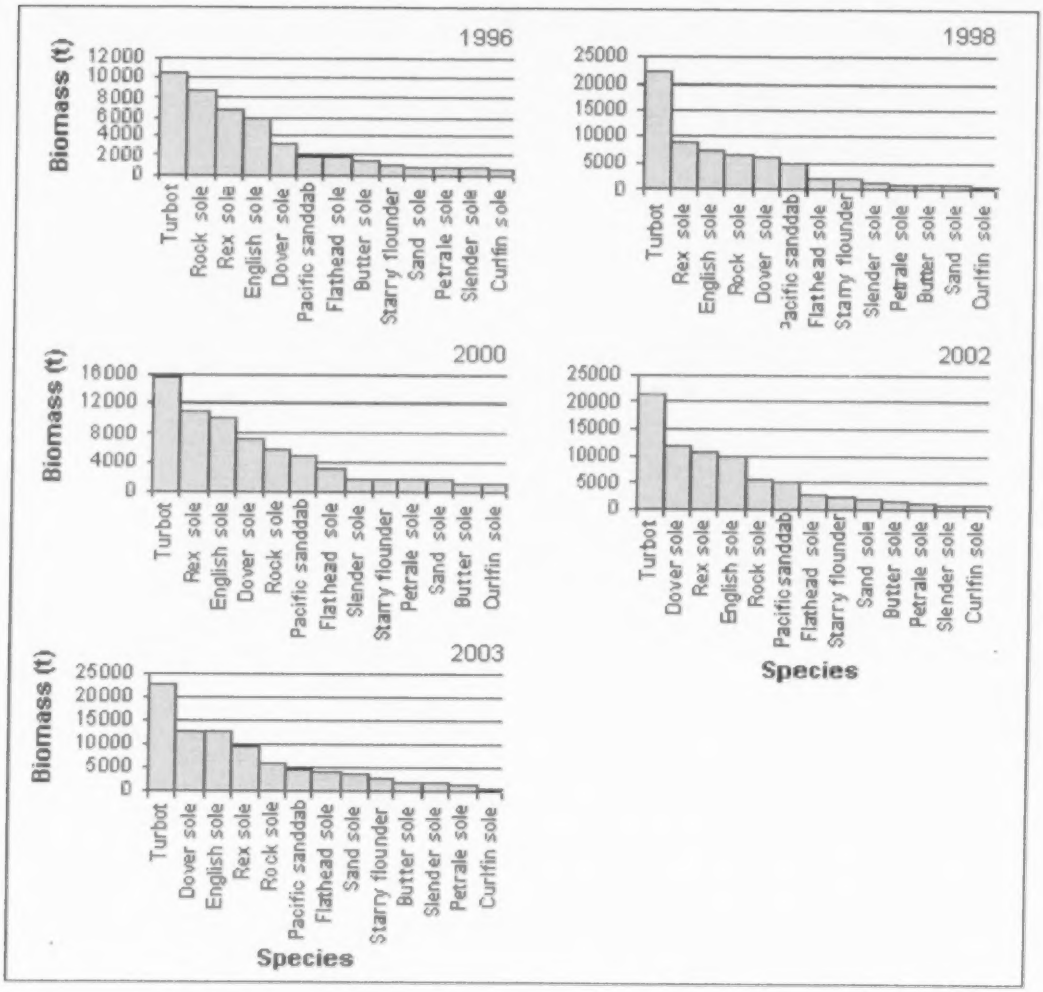

Figure 13. cont'd

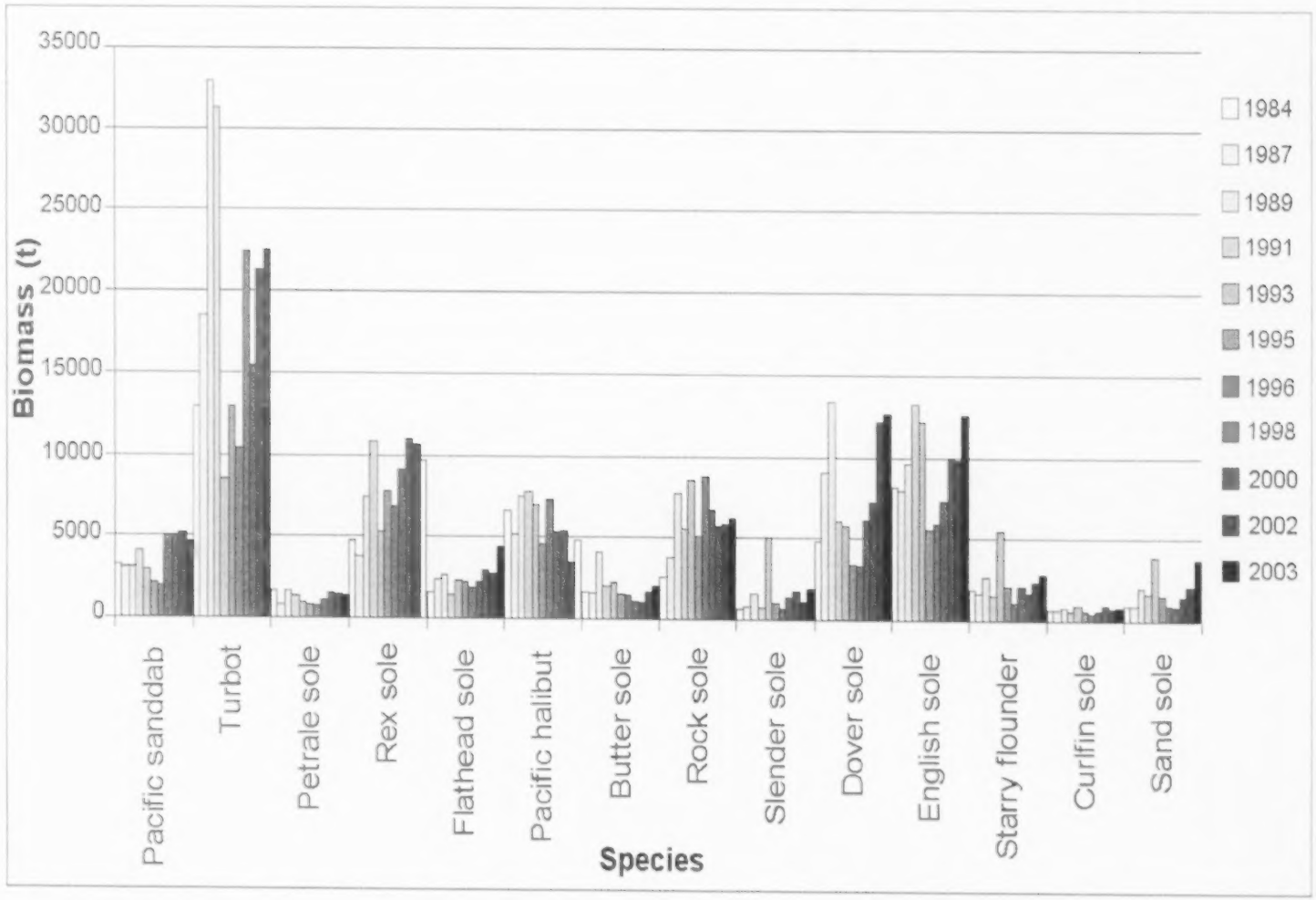

Figure 14. Summaries of annual biomass for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003 determined from backtransformed ln(CPUE).

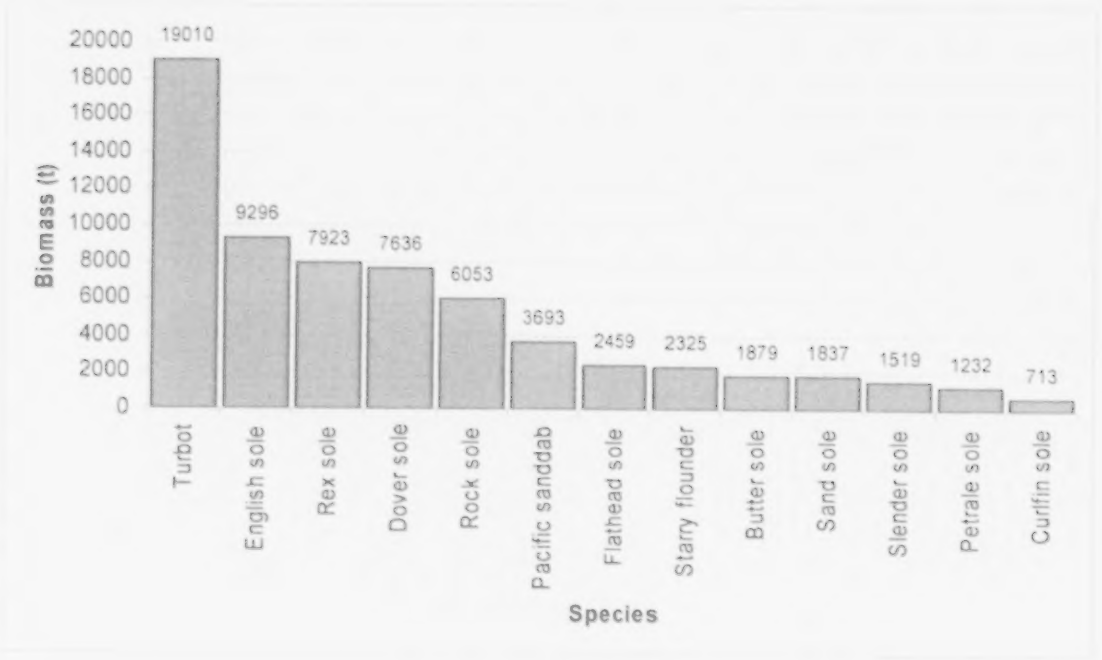

Figure 15. Mean annual biomass for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003.

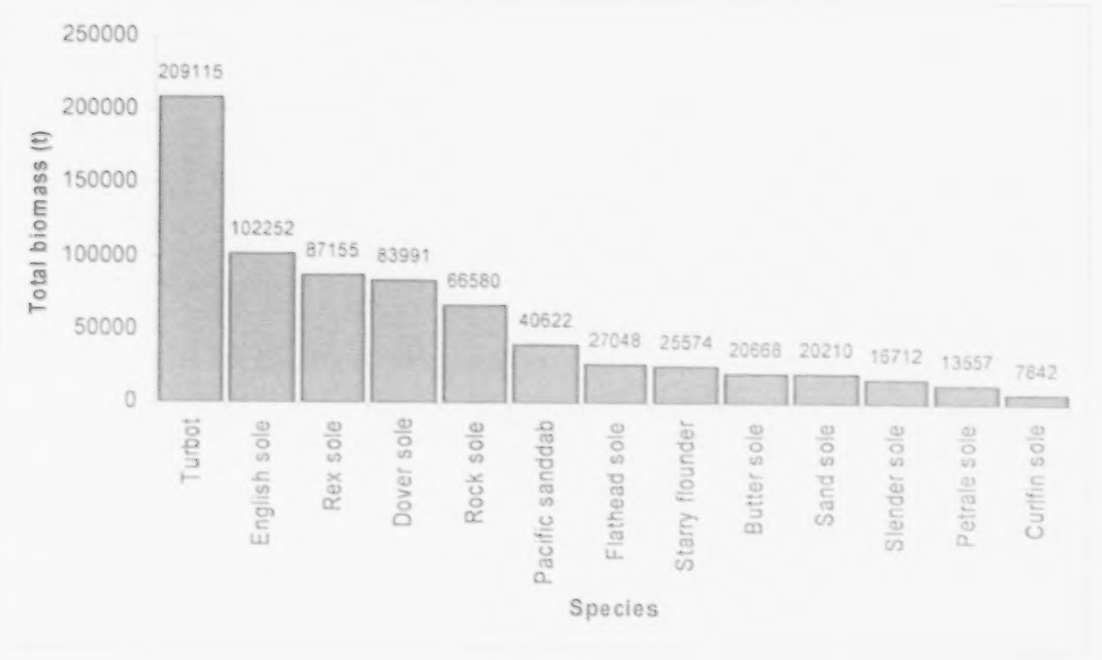

Figure 16. Total biomass for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003.

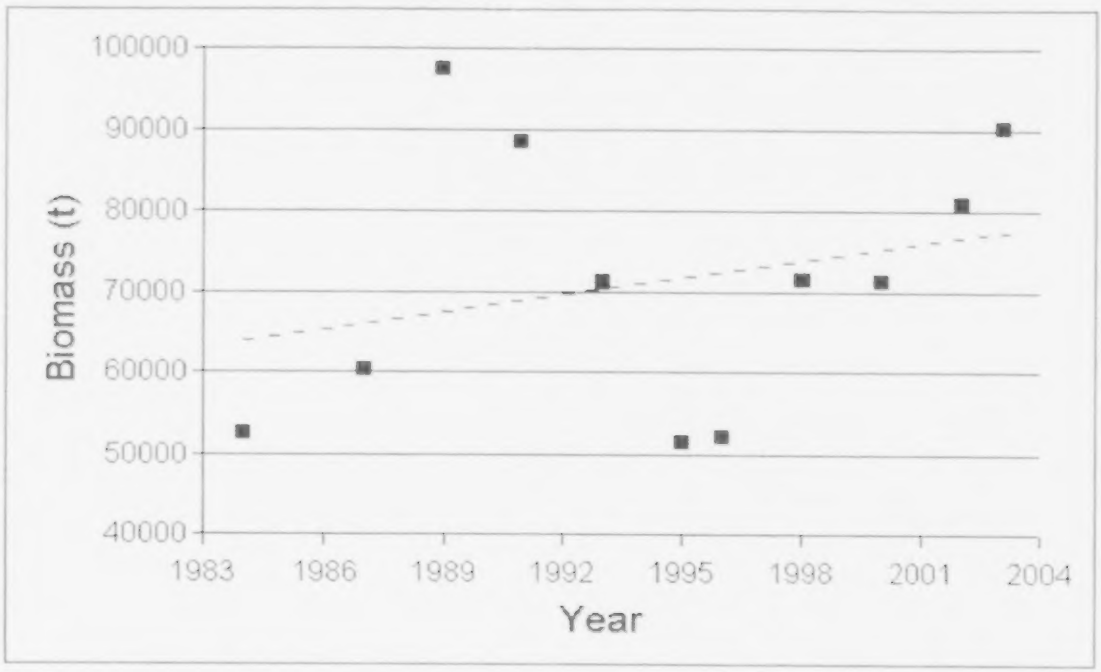

Figure 17. Overall trend in biomass for flatfish species caught on the Hecate Strait Assemblage bottom trawl surveys, 1984-2003.

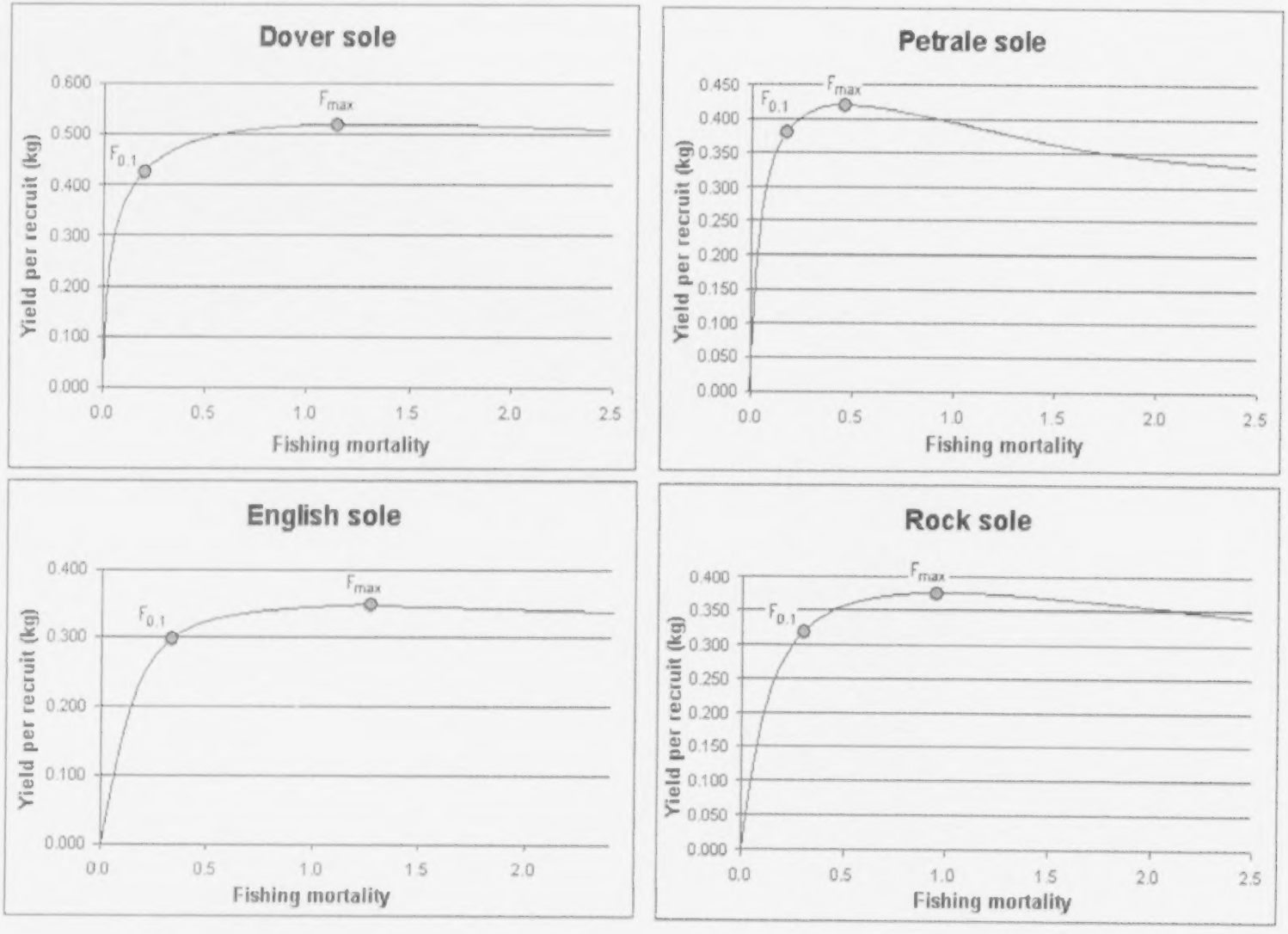

Figure 18. Yield per recruit curves determined from population simulations for west coast Vancouver Island Dover Sole and Petrale Sole and Hecate Strait English Sole and Rock Sole.

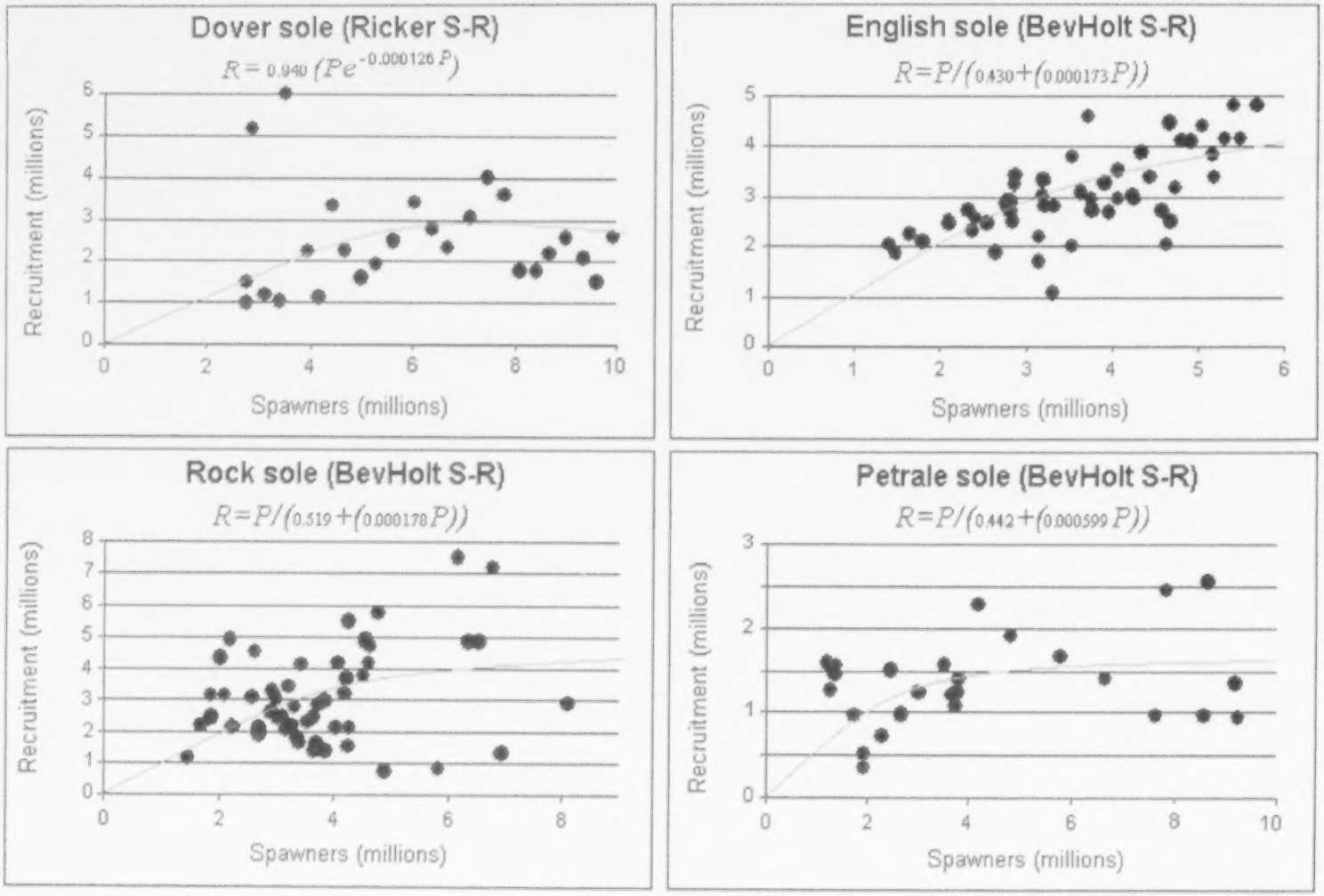

Figure 19. Stock recruitment relationships used in population simulations for west coast Vancouver Island Dover Sole and Petrale Sole and Hecate Strait English Sole and Rock Sole.

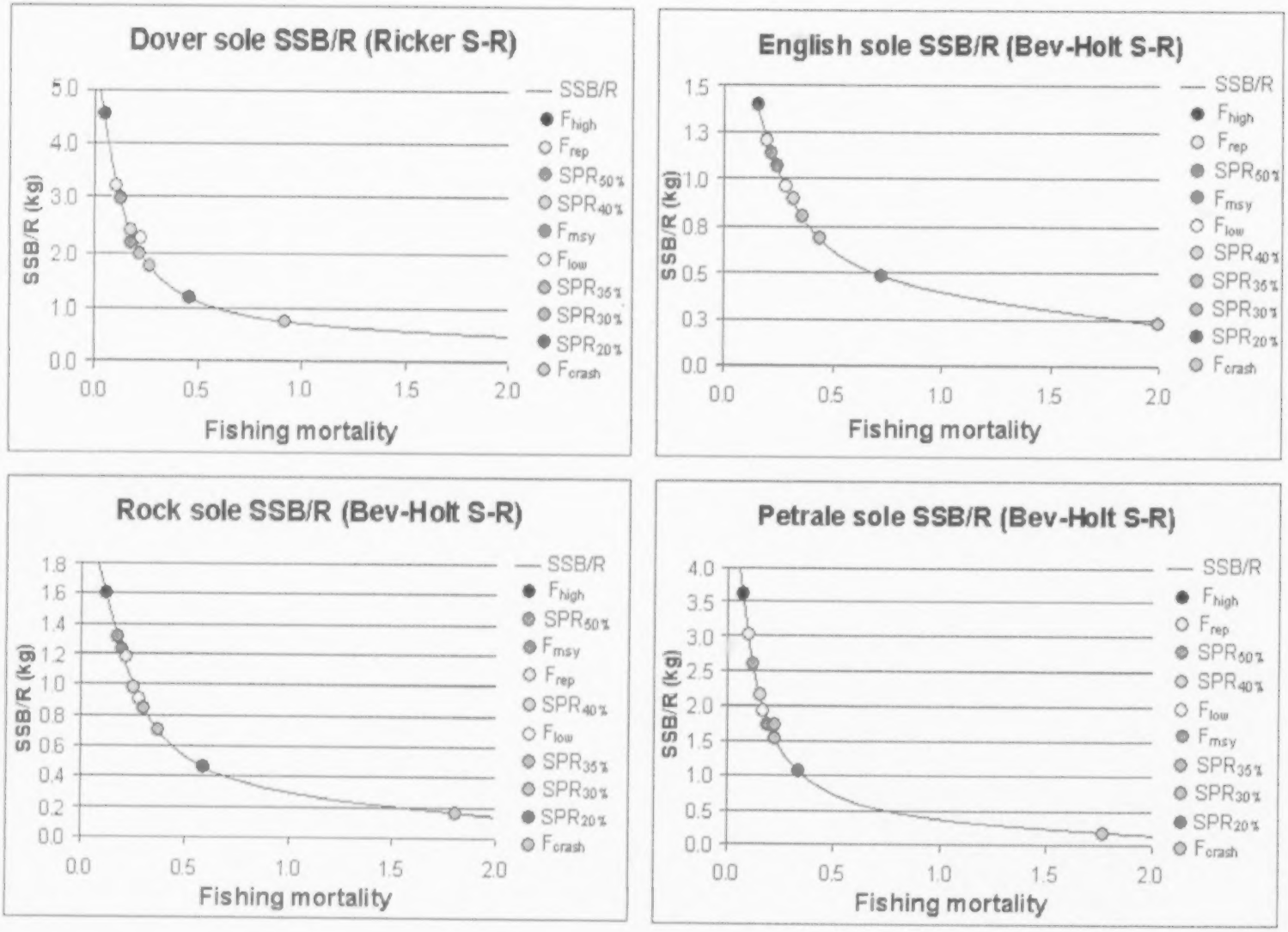

Figure 20. Spawning stock biomass per recruit curves with reference points for west coast Vancouver Island Dover Sole and Petrale Sole and Hecate Strait English Sole and Rock Sole.

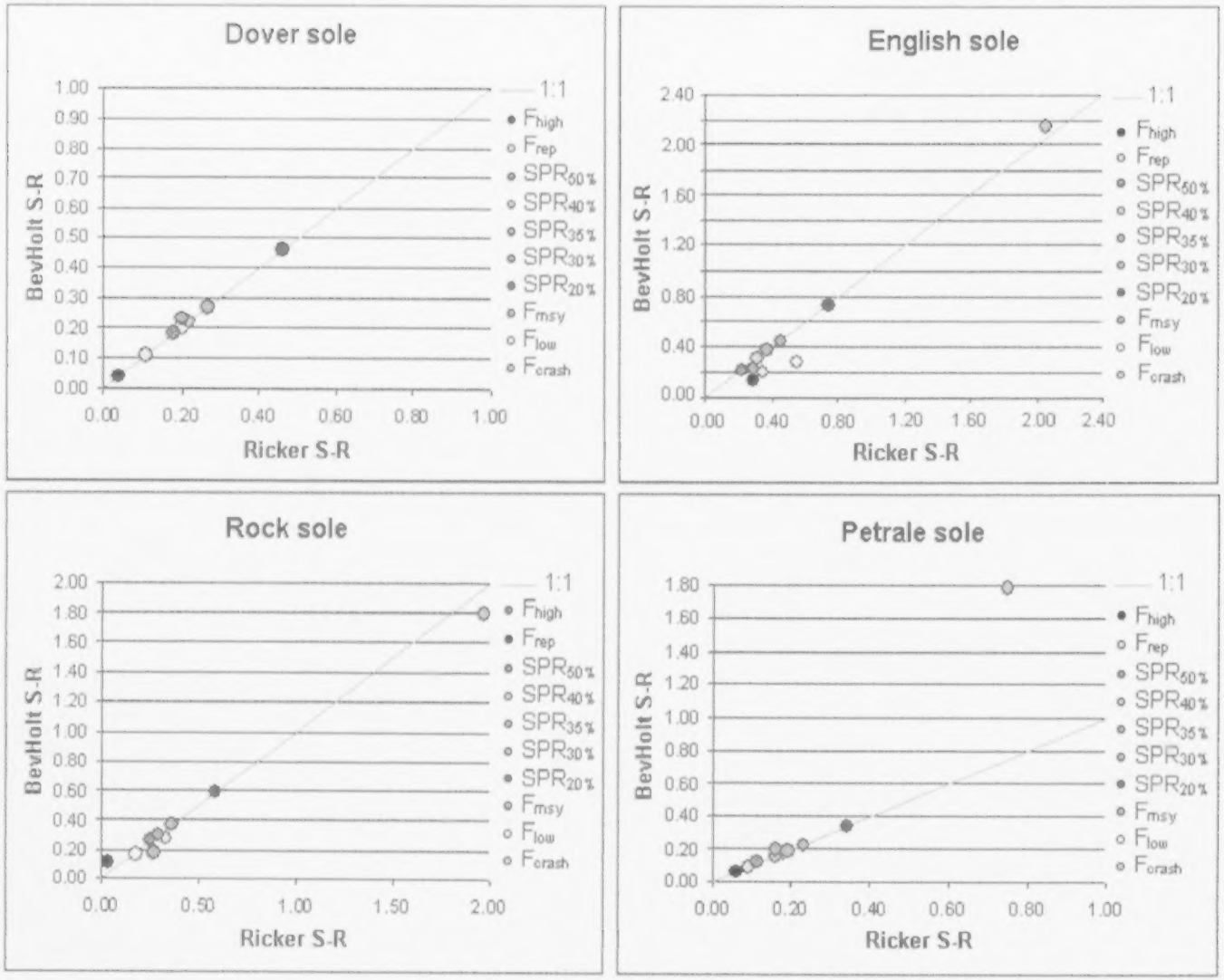

Figure 21. A comparison of the effect of the stock recruitment relationship on reference point estimates. The diagonal red line indicates 1:1 correspondence.

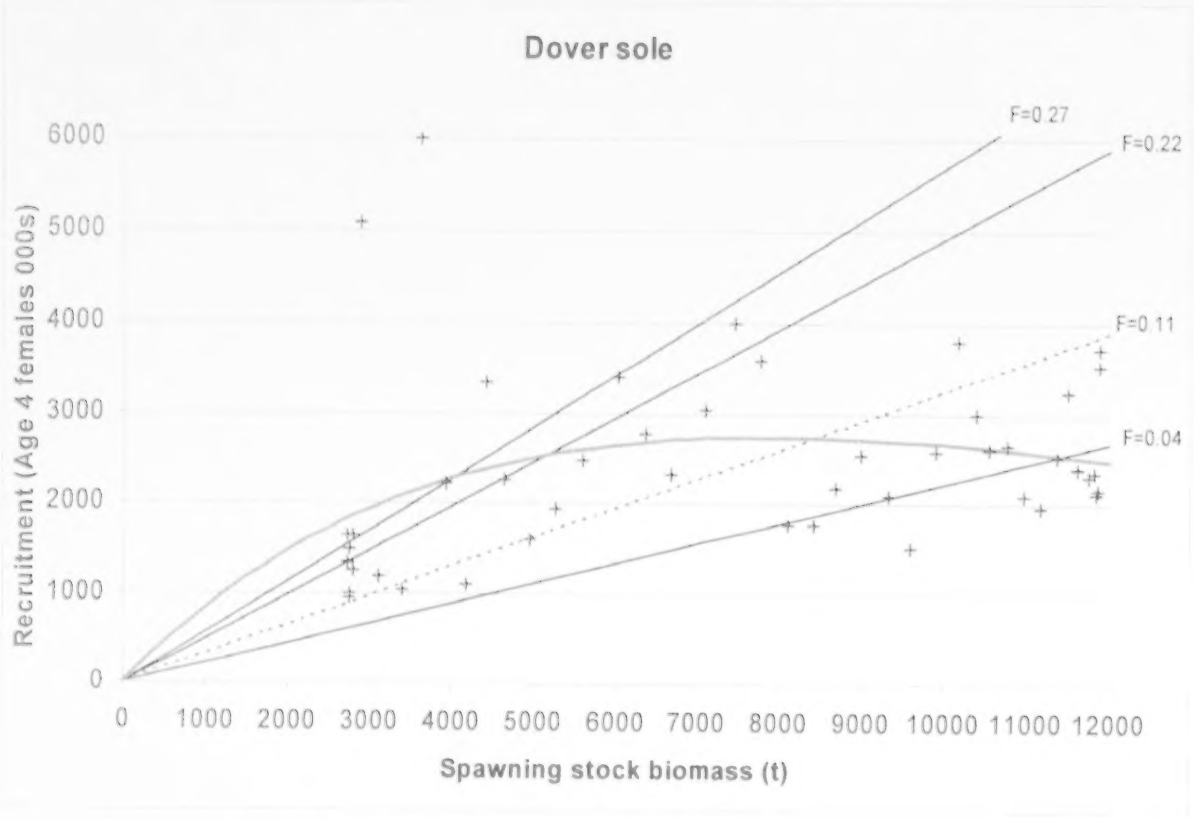

Figure 22. Spawning per recruit (SPR) superimposed on the stock recruit data for west coast Vancouver Island Dover Sole. The relationship between spawner per recruit levels derived from SPR analysis and survival ratios (R/S) estimated from spawning-recruitment scatter plots. A particular constant rate of fishing mortality has1:1 correspondence with an associated SPR level which can be inverted and used as the slope of a straight line through the origin of the S-R scatter plot. The dashed line indicates the average survival ratio required to support the corresponding constant F. Higher levels of F require higher survival ratios (higher slopes). The dashed line is the replacement line referred to as F_{rep}. The corresponding level of SPR is called the replacement SPR. If survival ratios are above this level the population will decrease and if they are below this level the population will increase.

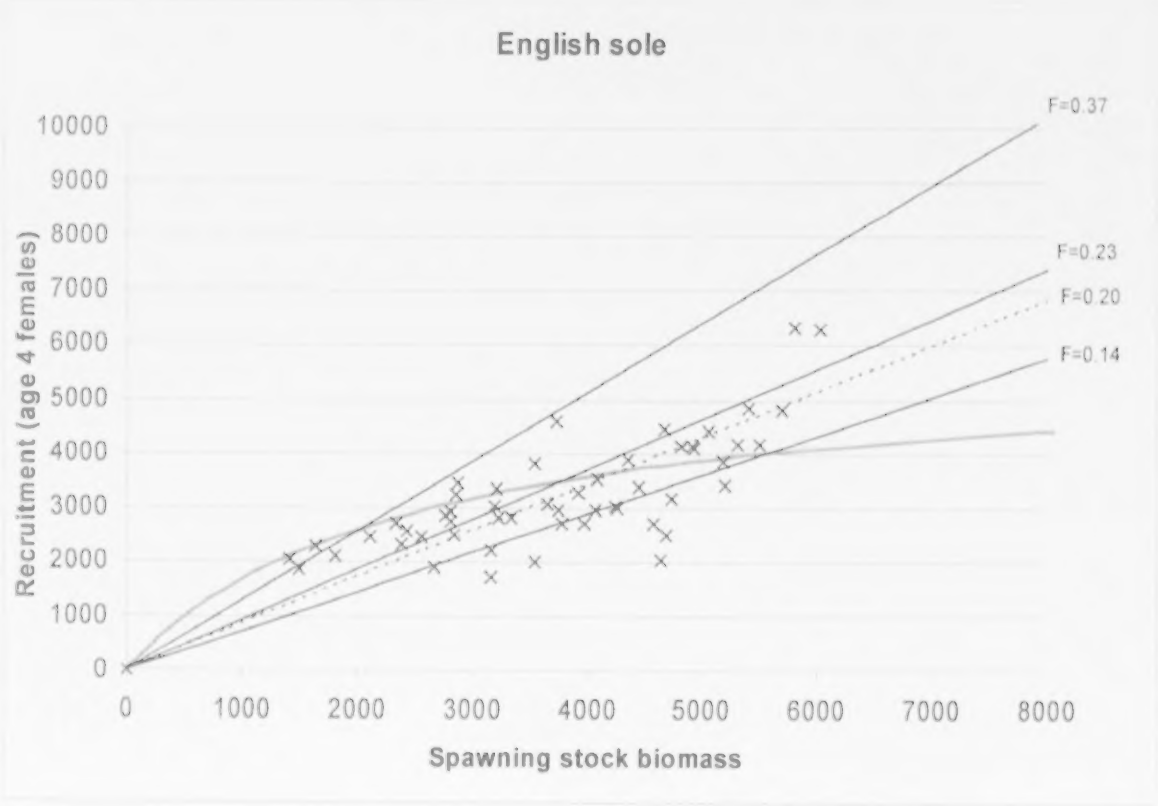

Figure 23. Spawning per recruit (SPR) superimposed on the stock recruit data for Hecate Strait English Sole. The relationship between spawner per recruit levels derived from SPR analysis and survival ratios (R/S) estimated from spawning-recruitment scatter plots. A particular constant rate of fishing mortality has1:1 correspondence with an associated SPR level which can be inverted and used as the slope of a straight line through the origin of the S-R scatter plot. The dashed line indicates the average survival ratio required to support the corresponding constant F. Higher levels of F require higher survival ratios (higher slopes). The dashed line is the replacement line referred to as F_{rep}. The corresponding level of SPR is called the replacement SPR. If survival ratios are above this level the population will decrease and if they are below this level the population will increase.

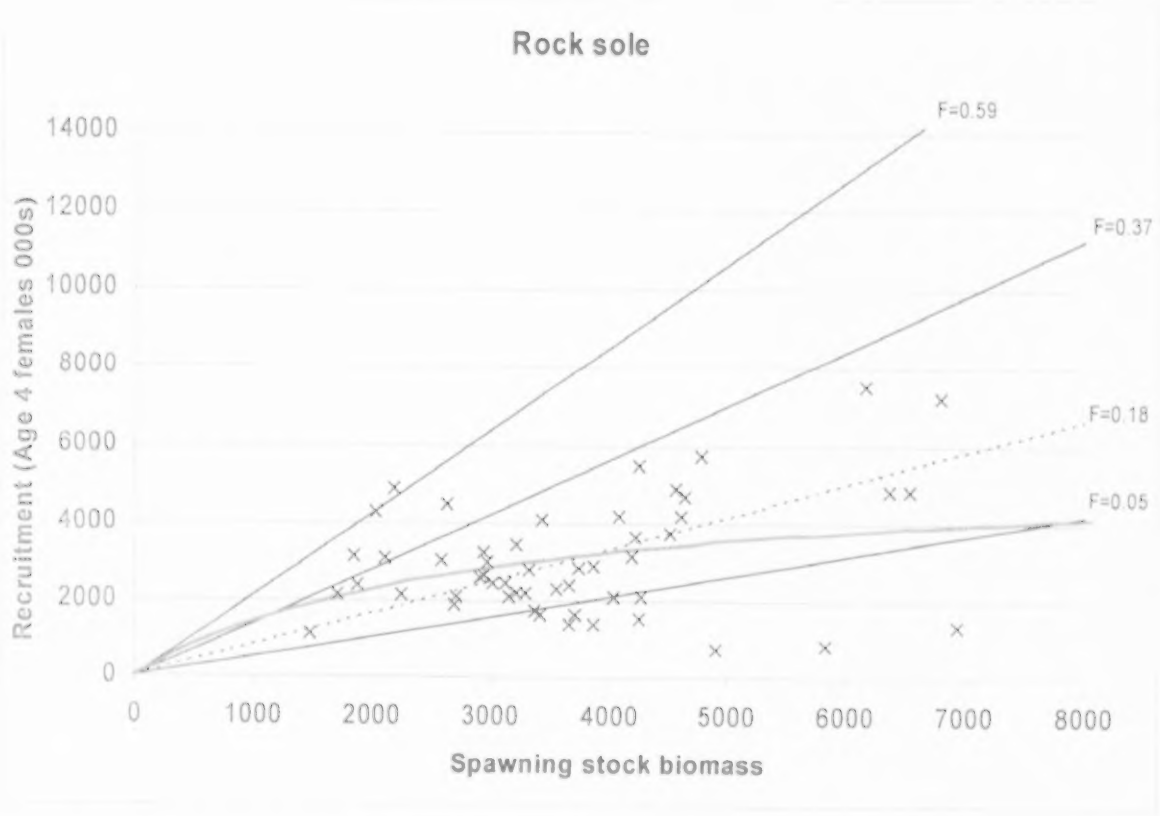

Figure 24. Spawning per recruit (SPR) superimposed on the stock recruit data for Hecate Strait Rock Sole. The relationship between spawner per recruit levels derived from SPR analysis and survival ratios (R/S) estimated from spawning-recruitment scatter plots. A particular constant rate of fishing mortality has1:1 correspondence with an associated SPR level which can be inverted and used as the slope of a straight line through the origin of the S-R scatter plot. The dashed line indicates the average survival ratio required to support the corresponding constant F. Higher levels of F require higher survival ratios (higher slopes). The dashed line is the replacement line referred to as F_{rep}. The corresponding level of SPR is called the replacement SPR. If survival ratios are above this level the population will decrease and if they are below this level the population will increase.

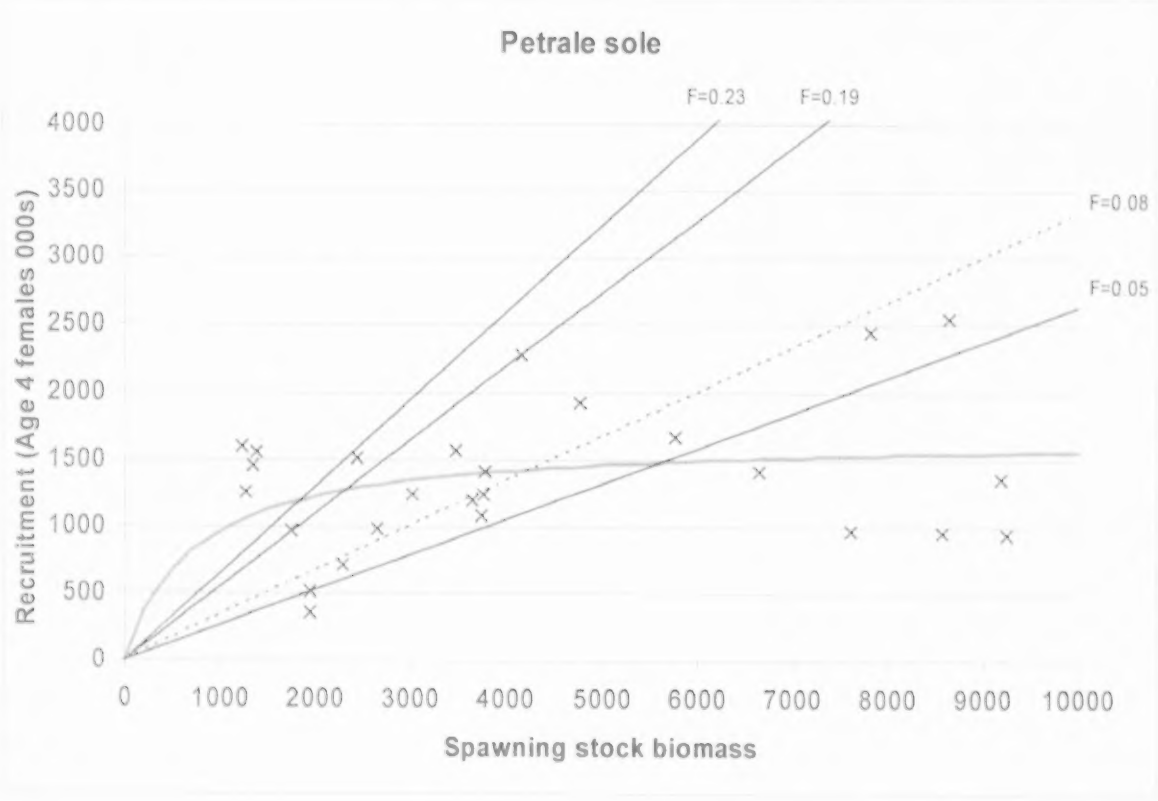

Figure 25. Spawning per recruit (SPR) superimposed on the stock recruit data for west coast Vancouver Island Petrale Sole. The relationship between spawner per recruit levels was derived from SPR analysis and survival ratios (R/S) estimated from spawning-recruitment scatter plots. A particular constant rate of fishing mortality has1:1 correspondence with an associated SPR level which can be inverted and used as the slope of a straight line through the origin of the S-R scatter plot. The dashed line indicates the average survival ratio required to support the corresponding constant F. Higher levels of F require higher survival ratios (higher slopes). The dashed line is the replacement line referred to as F_{rep}. The corresponding level of SPR is called the replacement SPR. If survival ratios are above this level the population will decrease and if they are below this level the population will increase.

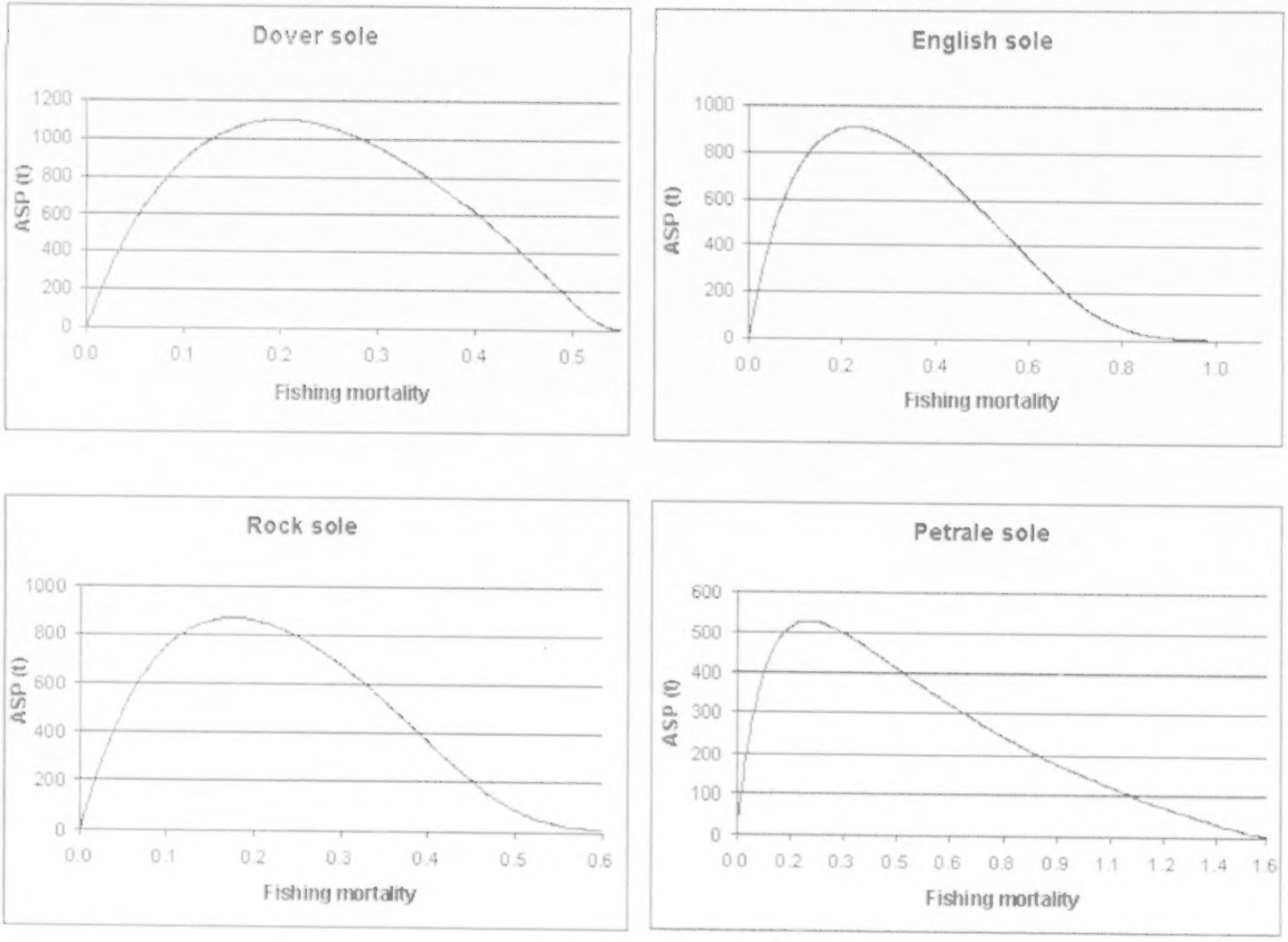

Figure 26. Annual surplus production curves determined from populations simulations for west coast Vancouver Island Dover Sole and Petrale Sole and Hecate Strait English Sole and Rock Sole.